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# Performance appraisal of Variants of Hybrid Extended Kanban Control System by Analytical modeling and by using Discrete Event Simulation study in Lean Manufacturing Systems

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**Abstract**

Predictive simulation is a sophisticated investigative technology, which is employed to support intricate resolutions in the business and organizations. This paper gives an initiative regarding the relative performance evaluation of the proposed new mechanisms for the synchronization of systems facilities and the other machines in multi line, multi stage manufacturing environment. In the intelligent manufacturing environment, these methodologies are mainly to control and to optimize the facilities and the resources available using discrete event simulation process to model, appraise and contrast the process parameters. The performance of Hybrid Independent Extended Kanban Control System (HEKCS) and Hybrid Simultaneous Extended Kanban Control System (HSEKCS) was developed, modeled and compared their advantages and also studied their effect in a typical multi line, multi stage assembly manufacturing system to evaluate the performance parameters like Average Work-in-Process, Production rate and Average Waiting Time for 2880 hrs for both analytical and Simulation studies were performed with exponentially subjecting demands.

***Keywords:***

Extended Kanban Control System (EKCS);
Hybrid Independent Extended Kanban Control System (HEKCS); Hybrid Simultaneous Extended Kanban Control System (HSEKCS); CONWIP;

Performance parameters.

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## 1. Introduction

The inclusive market structure has been changed for the few decades significantly due to brisk advance of technology. Consequently, for the foreign investors local markets have become easily

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reachable in their newly ascertained territory because of advanced technology they are not only able to perform well in addition they are even able to excel much. Global aggression in between the manufacturing firms predominantly in computer, automotive and electronics industries, compel them to sustain with novel perceptions and even practically fit in into their daily manufacturing schedule continually endeavor to their viable benefits.

Therefore these firms are act in responding to the brash out of customer ordering via Internet and e-commerce by budging to make-to-order environment and re-configurable mechanized equipment. JIT [Just-in-time] concept depends on authentic demand causing the discharge of work into the production system, and drawing the work all the way through the system to fill up the system demand order. In these situations the kanban practice is a sort of revolution. This practice is originated from the Toyota Production System to improve production rate or throughput and minimize the inventory for a lean manufacturing environment.

It intends at minimising manufacturing lead times and the WIP [Work-in-Process] levels in the production plant. Though, the limited relevance of Kanban has exacerbated researchers to find substitutes to this control approach. New pull policies therefore have been build up. For the production analysts Predictive simulation permits to go ahead basic data models and trends, simple patterns, variability and interactivity and also appending consciousness of process intricacies. Production analysts are able to completely understand during process modeling, process change effect on the business performance. The first step is only identifying in the data the opportunities and threats, process simulation facilitates solutions to be aimed, investigated and optimized before the decisions were made and the corresponding action is taken.

In the pull production systems, optimization of production control is attained by practically comprehending numerous manufacturing activities into dissimilar stages of production and after that synchronizing the discharge of parts into every stage, with the influx of demands of the customer for final manufactured goods.

ML Spearman et al proposed CONWIP policy which provides safety stock to reduce effect of variation and demand fluctuations in JIT environment. George L & Yves D et al2 The two variants of Extended Kanban Control System have been found more productive in extending to manufacturing industrial applications. They developed the Extended Kanban Control System (EKCS) pull production control mechanism which consists of base stock and kanban control system. They found that, these policies are more useful in assembly manufacturing system. The authors have proposed Hybrid mechanisms where Extended Kanban Control system (EKCS) is combined with CONWIP; i.e, Hybrid Extended Kanban Control System (HEKCS) to exploit the combined advantages and also to study their effect in a typical manufacturing environment. Simulation studies were performed using Process Model software to evaluate the performance measures like production rate, average waiting time and average Work in Process for all the control mechanisms.

## 2. Problem Definition

As shown in fig-1, an assembly manufacturing system considered having three machines in series making three dissimilar processes on parts in sequential manner. One cell is formed by three manufacturing facilities. Each line is having three machines, Where each line i =1, 2, 3.

After completion of all the three operations sequentially a part will be sent to the final shipping station. There is one production authorization kanban card to permit the manufacturing for the flow line initial position. The assembly system is modeled as network diagrams for the two variants of Hybrid Extended Kanban Control System HEKCS, namely HSEKCS [Hybrid Simultaneous Extended Kanban Control System] and HIEKCS [Hybrid Independent Extended Kanban Control System].

The authors enlarged in this work the decomposition – supported method of Di Mascolo et.al to analyze the Extended Kanban Control System (EKCS) and Hybrid control system, and the synchronization station with three feeding queues.

With the external demands which arrive according to Exponential process are first synchronized with the finished parts of a stage then with the kanbans of the next stage the cumulative arrivals are synchronized in the system.

By means of Queuing networks, Markov Continuous Time Chains and by using Buzen's algorithm, Jackson's algorithm, Gordon and Newell theorm and other standard stochastic mathematical related techniques the same problem is analytically modeled. With a warm-up period of 15000 seconds, the entire assembly system is modeled by using discrete event simulation software Witness for the simulation. The manufacturing system processing times equal to 15 min follow exponential distribution. The demand also considered to follow exponential distribution with the arrival rate of 25 minutes to 95 mintues. The entire manufacturing assembly line considered is simulated for the time of 1,72,800 minutes. (4 months at 3shifts per day with 8hrsof work per shift) with 20 repetetions.

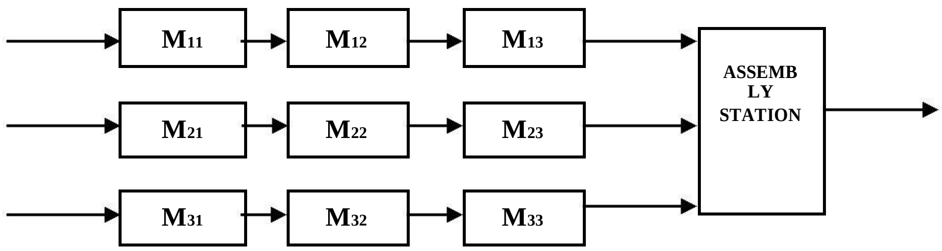


Figure 1. *A multi-stage, multi-line assembly production control system.*

For the multi-stage, multi-line assembly manufacturing system the simulation and analytical analys is done and the related performance parameters Throughput or Production Rate, Average Average WIP and Average Waiting Times and were worked out and assessed with each other policy.

**3. CONTROL STRATEGIES**

EKCS [EXTENDED KANBAN CONTROL SYSTEM]:

Combining the Kanban Control and Base stock control systems Extended Kanban Control System was proposed as a general approach to pull production control policy in manufacturing. In this EKCS strategy whenever a customer demand enter in to the production system it is emphasized at all different the stages of the system. That is whenever the production kanban signal associated with the stage is available, then only a part is discharged from up stage to the down stage.

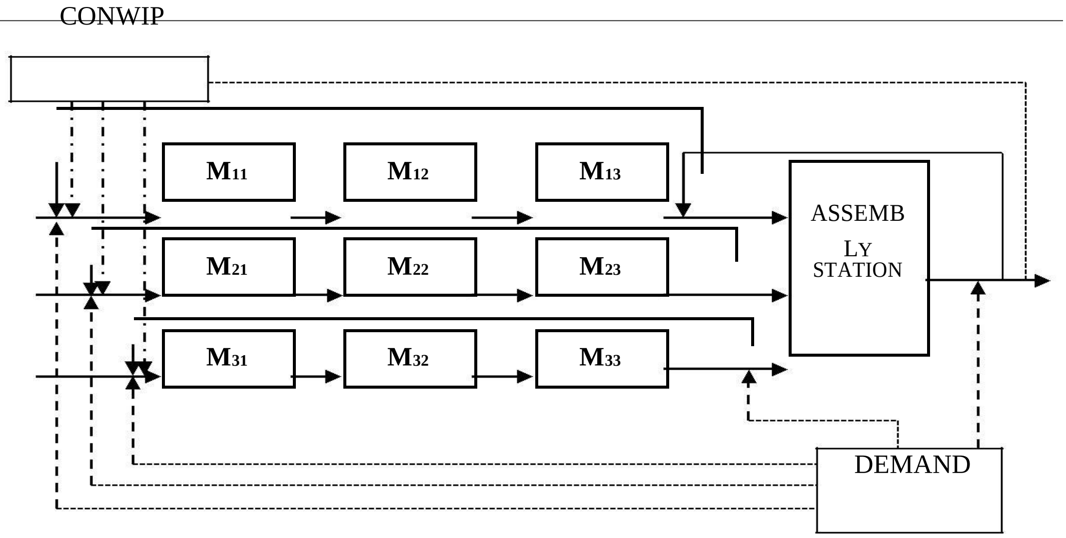


Figure 2. *Diagrammatic Representation of HSEKCS System*

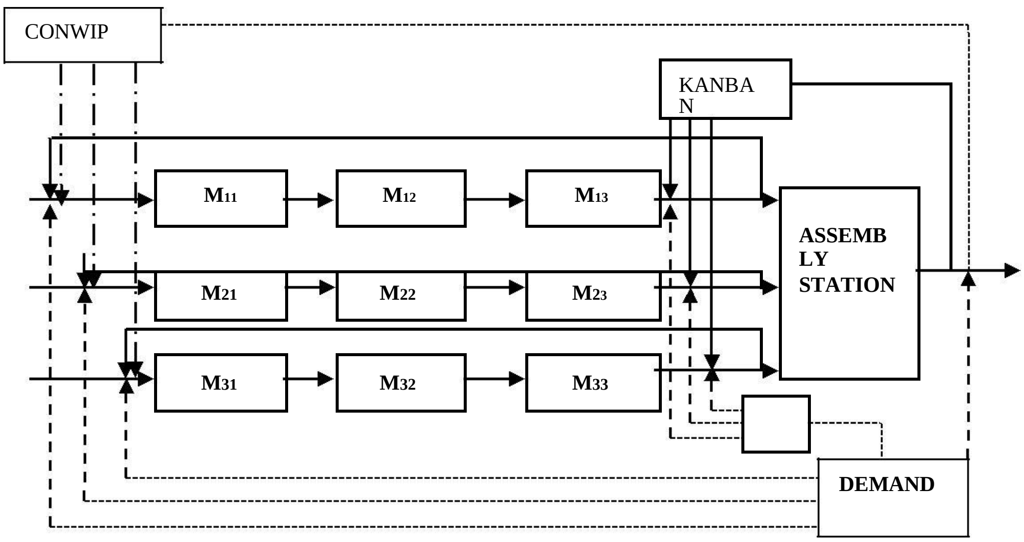


Figure 3. *Schematic Diagram of HIEKCS Control Policy*

HEKCS [HYBRID EXTENDED KANBAN CONTROL SYSTEM]:

This is the novel control policy put forward by the authors, by hybridizing the pull control policies CONWIP and EKCS thus establishing a tight control on the parameter Work in Process in the production system. Because of t the intrinsic EKCS mechanism this policy also reacts quickly to the customers demands. The two variants of this mechanisms HSEKCS and HIEKCS are shown in the Figures 4 and 5 may have the combined advantages of EKCS and CONWIP policies.

**4. Performance Modelling Tools**

There are two classes of Performance evaluation techniques for Production systems; performance modeling and Performance measurement. System Performance measurement is conceded on accessible operational methods and is commonly used for recognition of malfunctions, scrutinizing of key variables and for feasible reconfiguration. In the manufacturing environment data collection and analysis are regularly done as an element of reporting MIS [Management Information Systems].

Production systems performance modeling can be either analytical modeling or simulation modeling. In the manufacturing environments, conservatively discrete event simulation technique has been extensively agreed and employed for the study of problems in design and operational activities. Stochastic Petrinets, Queing theory, Markov chains such analytical modeling tools are becoming now growingly accepted and emerging techniques for substitute to simulation tools.

Analytical Models: These models can be resolved either by using numerical techniques or in the closed form. The model and its result can be fully authenticated when a biddable analytical model has been prepared. Distinctively, in a short time such models can be analyzed and about system quick feedback performance is possible. Frequently to validate simulation models analytical models can be used and vice versa.

Simulation Models: For analyzing and building the comprehensive models of production systems the technique Discrete Event Simulation modeling offers the scope. Whenever the number of simulation runs is made big, the system performance approximations will be very specific. Since its power and simplicity simulation technique is relatively accepted. Authors of this paper used Witness software for conducting the simulation process.

Process Parameters

Throughput or Production rate: With respect to the demand the rate at which jobs departs the station.

Average waiting Time: The average time waited in the queue at all the processing stations for a part to be released from the system.

Average Work in Process: This number relies on the arrival rate of demands. This is in between stations the Average quantity of semi finished goods waiting and the number of finished goods are waiting for the dispatch.

Simulation analysis and Mathematical modeling of multi-line, multi-stage assembly manufacturing system for both of the hybrid control mechanisms namely HSEKCS and HIEKCS is done and the performance measures like Average Waiting Time, Average Work-in- Process and Production rates were calculated and evaluated relatively for every other process.

**5. Assumptions**

1. For the assembly manufacturing system the product demand inter arrival time follows Stochastic Process.

2 There are two inventory points for each stage at the beginning and at the end for every manufacturing facility.

3 No transportation times between production stages considered.

4 The production system for assembly consists of three stages. Demand in each stage follows exponential distribution.

5 raw parts are always available in the queue and the system processes only a single part type.

6 The servicing follows FIFO queue at each node in the network.

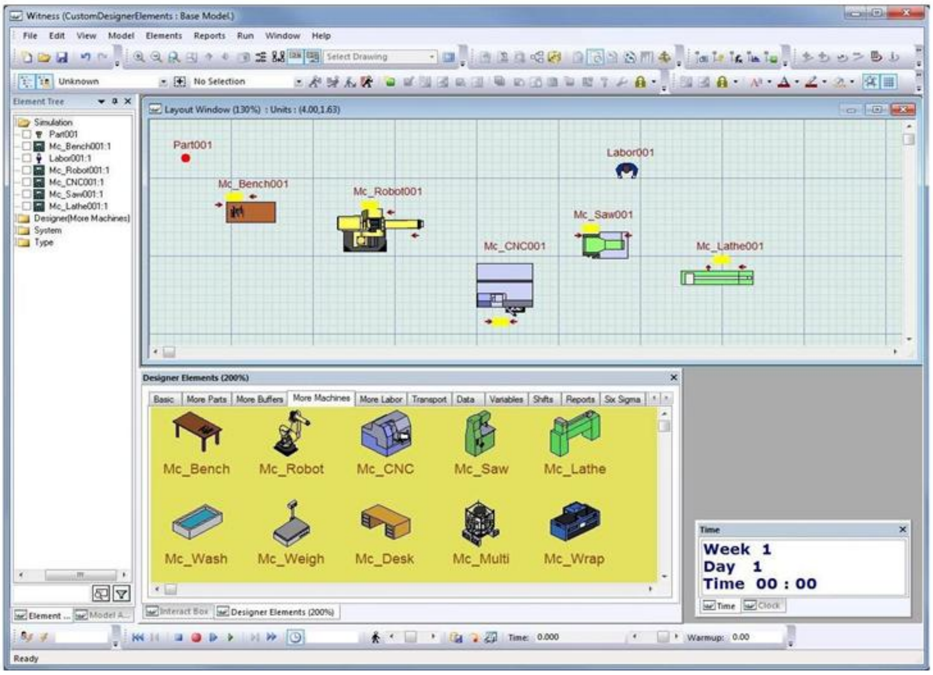


Figure 4.*WITNESS Software Modeling window*

**6. Results & Graphs**

Table 1. For a mean time of 35 min. relative Production Rate performance assessment of the Pull production control systems.

| DEMAND | By Simulation Process | | By Analytical Process | |
|---|---|---|---|---|
| | HIEKCS | HSEKCS | HIEKCS | HSEKCS |
| E(95) | 258 | 244 | 267 | 259 |
| E(85) | 272 | 285 | 281 | 311 |
| E(75) | 305 | 311 | 316 | 341 |
| E(65) | 321 | 333 | 339 | 365 |
| E(55) | 339 | 347 | 351 | 375 |
| E(45) | 359 | 370 | 377 | 387 |
| E{35} | 380 | 378 | 396 | 392 |
| E(25) | 380 | 379 | 405 | 401 |

Table 2. For a mean time of 35 min. relative Average Waiting Time performance assessment of the Pull production control systems.

| DEMAND | By Simulation Process | | By Analytical Process | |
|---|---|---|---|---|
| | HIEKCS | HSEKCS | HIEKCS | HSEKCS |
| E(95) | 326.94 | 193.54 | 339.14 | 212.2 |
| E(85) | 327.26 | 144.47 | 340.80 | 166.4 |
| E(75) | 282.90 | 127.23 | 308.30 | 142.9 |
| E(65) | 281.84 | 111.61 | 289.10 | 118.5 |
| E(55) | 269.57 | 118.23 | 275.20 | 116.7 |
| E(45) | 279.97 | 109.82 | 289.30 | 120.6 |
| E{35} | 279.26 | 109.88 | 304.70 | 125.8 |
| E(25) | 313.29 | 118.89 | 351.80 | 130.2 |

Table 3. For a mean time of 35 min. relative Average WIP performance assessment of the Pull production control systems.

| DEMAND | By Simulation Process | | By Analytical Process | |
|---|---|---|---|---|
| | HIEKCS | HSEKCS | HIEKCS | HSEKCS |
| E(95) | 11.40 | 5.35 | 11.81 | 5.56 |
| E(85) | 11.52 | 5.42 | 12.40 | 5.52 |
| E(75) | 11.65 | 5.77 | 12.42 | 5.71 |
| E(65) | 11.80 | 5.90 | 12.58 | 6.03 |
| E(55) | 11.84 | 5.97 | 12.61 | 6.08 |
| E(45) | 12.02 | 6.05 | 12.56 | 6.13 |
| E{35} | 12.10 | 6.16 | 12.61 | 6.12 |
| E(25) | 12.12 | 6.18 | 12.80 | 6.27 |

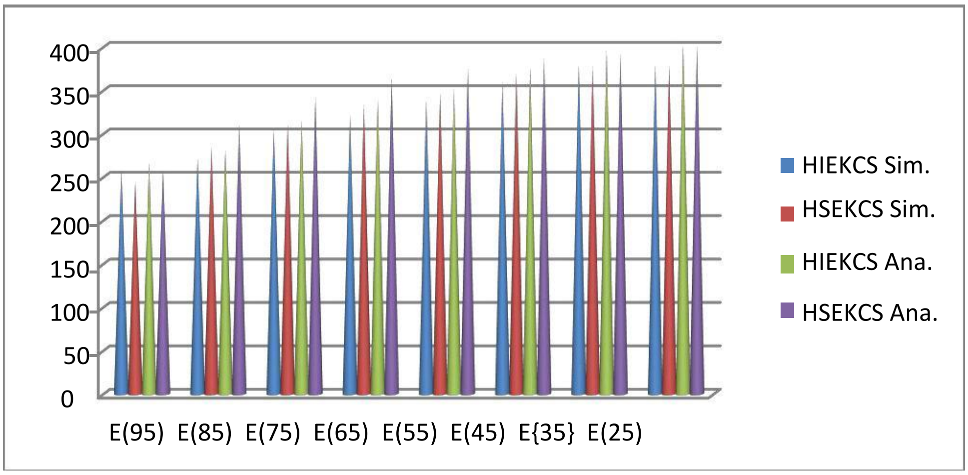


Figure 5.*For a mean time of 35 min. relative Production Rate performance assessment of the Pullproduction control systems.*

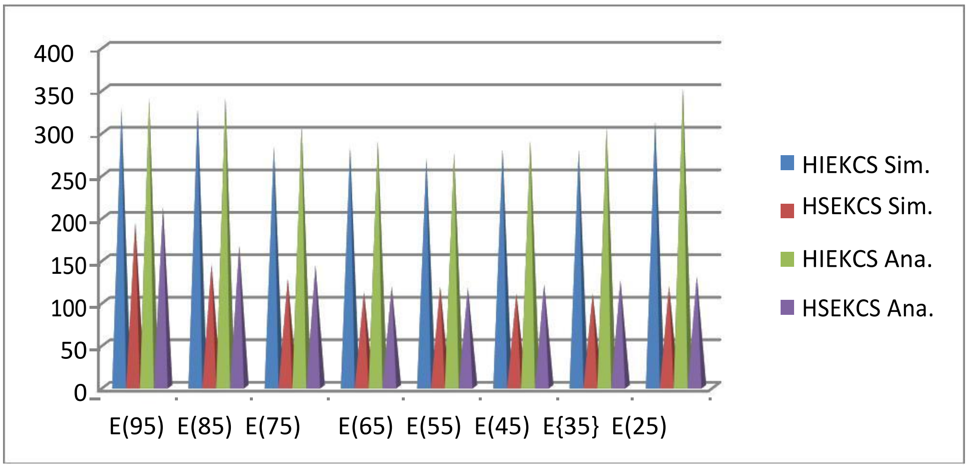


Figure 6. *For a mean time of 35 min. relative Average Waiting Time performance assessment ofthe Pull production control systems.*

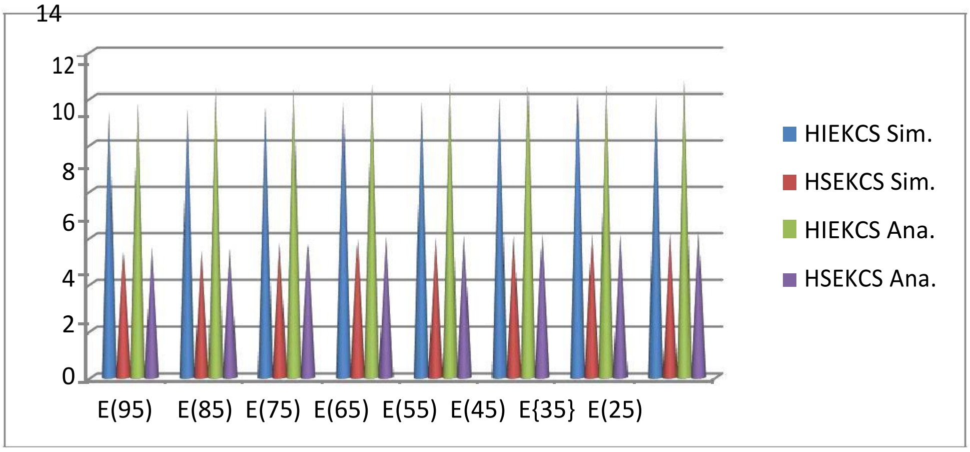


Figure 7.*For a mean time of 35 min. relative Average WIP performance assessment of the Pullproduction control systems.*

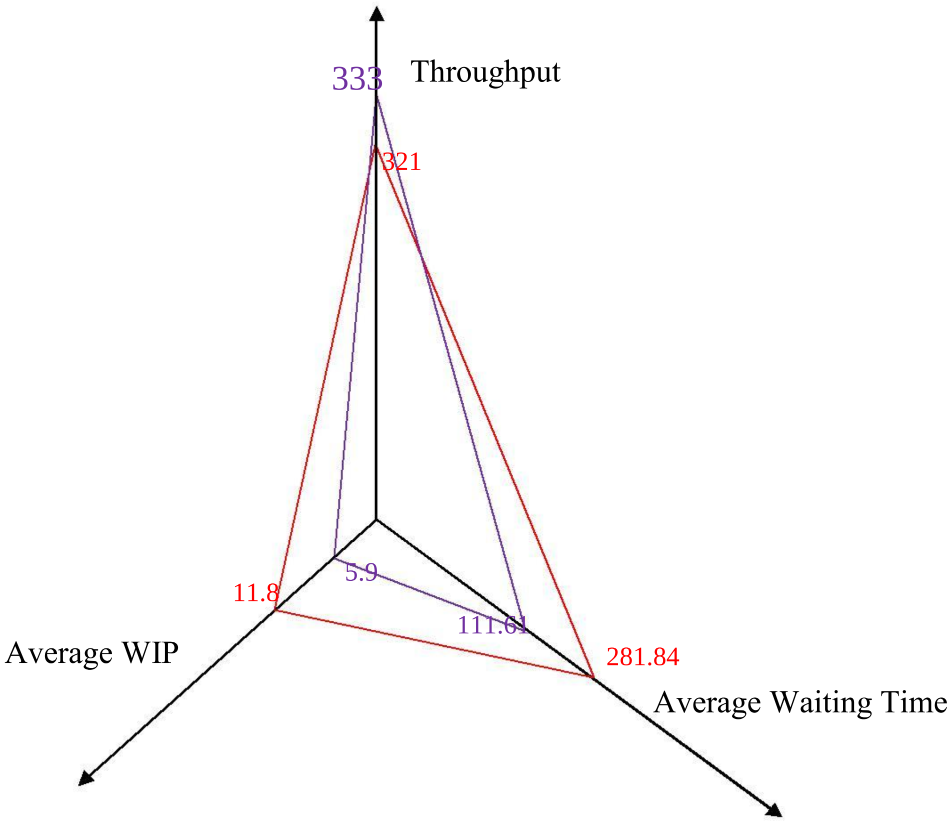


Figure 8. *Petal Diagram evaluating the Relative performance of Process Parameters for the Meantime of 25 min at Demand E(60) by Simulation Method.*

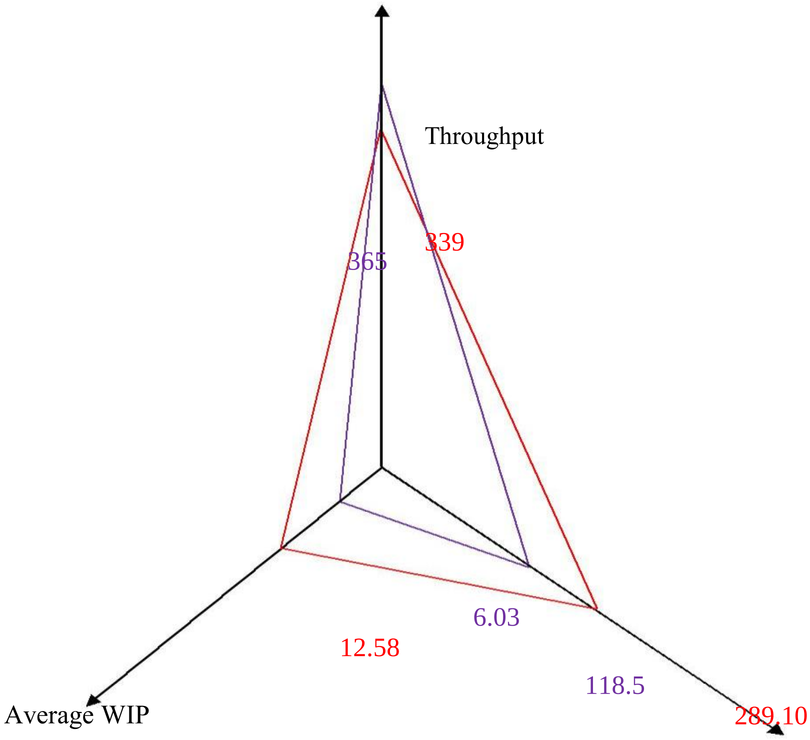


Figure 9. *Petal Diagram evaluating the Relative performance of Process Parameters for the Meantime of 25 min at Demand E(60) b Analytical Method.*

With the varying demand rates outcomes of process parameters production rate or throughput, average Work-in-Process and average waiting times and are shown in the relevant Figures and Tables for the analytical and simulation values of the two variants of hybrid mechanisms proposed. The tendency of the results is nearly analogous with the results of DiMascolo and Frein 1996and Mario DiMascolo 1996. The performance parameters trend been observed also being same in the graphs.

It is observed from these results once the demand rate increases, the production rate or throughput increases and parameters average Work-in-Process and average waiting times and turn down. In between the simulation model and analytical model there is some variation in results observed.

The average variation of error between analytical and simulation model is about 8.4%. Because of approximation practices and assumptions involved in simulation errors, in analytical model which comprise modeling error and also in sampling error and error in parameter estimation in simulation model and in computer-programming error. The General permissible error is up to 15% (Law 1991). Therefore the ranges of errors are within the acceptable limits.

The process parameters are influenced by three variables base stock (S), demand rate or Arrival rate or (λ) and the service rate (μ).

The assembled parts are shipped to the customer once the demand is fulfilled and when the base stock i.e. λ<S. After the average Work-in-Process and average waiting times are less and production rate will be more.

Once there is a gradual increase in demand rate the average Work-in-Process and average waiting times will turn down and the production rate or throughput increases gradually.

This tendency will be continued up to the demand rate is equivalent to base stock, λ= S, and the reverse trend is perceived when that demand rate is more than base stock i.e. λ>S the performance parameters are to perform in a converse mode.

It is observed from the results in HSEKCS policy no joins are present in synchronization station at the end of the second line therefore it causes increases in average WIP, average waiting time and more production rate.

At the synchronization station at end of third flow line the part and demand has to join which results an increase of average waiting time and average WIP.

In the case of HIEKCS the parts, assembly kanban and demand are synchronized and independently for the final assembly the parts are sent. Which results in HIEKCS minimum waiting times and Work in Process. In a Hybrid control policy a part trigged by an external signal [CONWIP] or by a internal signal [Kanban] is released from the last stage of first line. In HSEKCS mechanism less difference is observed for the lower values of λ and this difference increases gradually with increase in λ.

The performance parameters parts are affected by four individual parameters kanban signal, CONWIP signal and demand. It is essential that at the whole performance of HSEKCS is superior for lesser values λ. This is concluded that from the respective graphs and results individually for the process parameters considered, in both the varients of hybrid Extendedkanban Control Systems, optimum results are observed in HSEKCS.

The overall performance for higher values of λ would be the tradeoffs among the average Work–in-process (WIP), production rate and average waiting times. When comparing with HIEKCS, even Production rate is relatively low but much better results are observed in decrease in Average Work-in-Process and Average waiting time and in HSEKCS.

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