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Research paper

Scheduling and Control of Parts in FMS industry

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Abstract

This paper introduces scheduling of parts in Flexible Manufacturing System (FMS) environment by means of discrete-event simulation method. Modeling of FMS layout with 3 distinct part type, route and interval for each part is developed using Arena simulation. The ranking criterion is considered only for First-in-first-out (FIFO). Automatic Guided Vehicles (AGV) is used as a Material Handling System (MTH). In this paper a case study has been presented for effective utilization of machines and AGV in given FMS. Based on processing time for variety of parts according to their route priority the jobs are scheduled. The scheduling of the considered layout are evaluated and compared to 6 output measures which are avg. work in process (WIP), avg. queue time, avg. number of parts waiting, resource seized, machine instantaneous utilization and scheduled utilization for different replication length. The simulation outcomes are discussed in detail and conclusion has been drawn for various mentioned output measures.

Keywords: *Flexible Manufacturing system (FMS), discrete-event simulation, scheduling, FIFO, material handling system (MTH).*

1. Introduction

FMS comprises of highly automated CNC machines which is linked by a material handling system competent of producing wide variety of items. The benefit of an FMS is its high flextime in controlling for manufacturing resources and effort to manufacture a new product. FMS can achieve high efficiency of automated high-volume mass production while securing the flexibility for low-volume job lot production. In modern FMS, many of the existing time activities such as machining actions, part flow and tool changes are controlled by computers.

The intention of any manufacturing industry is to direct, towards to achieve a high scale of efficiency, flexibility and system utilization. The system utilization can be intended by changing the plant layout, by lowering the transfer time between stations and make span. Today's FMS seems to be promising technology as it has potential excellence with flexibility, which is significant for majority of manufacturing industries to remain competitive in a highly dynamic and varying manufacturing environment. Though the FMS is highly flexible problem arises when it comes to scheduling of an FMS for multiple part types and alternate routings, as it is complex in nature and requires proper planning to achieve better efficiency of the system. As scheduling is static problem, but when it comes to actual control the nature of FMS becomes dynamic. So simulation software can be the best tool to draw inferences and performance in real time. The intention of this paper is to present methodology to calculate effective utilization of machines and AGV by using simulation approach and to observe the nature of given FMS with different simulation length. Arena is a highly prominent discrete-event simulation package. A simulation study has been performed on FMS layout with different part variety and various output measures is analyzed for the specified FMS environment.

2. Literature Review

[1] K.C. Jeong and Y.D.Kim proposed a real-time scheduling method which adopts the simulation model and dispatching rules to control flexible manufacturing systems and created a scheduling method in which job dispatching rules varying vigorously based on facts from discrete-event simulation used to assess the dispatching rules. [2] Dr. Vijay Kumar addressed the distinctive type of Flexible Manufacturing System problems in requisites of make span, flow time, delay time etc. and proposed a different control strategies which include route flexibilities and various routing plan mixed together with five dispatching rules and examined different production volumes. [3] SZU-Yung David WU and Richard A. WYSK designed a technique for dynamic scheduling of an FMS and employed a discrete simulation to join multiple part dispatching rules based on their performance in a short term period. [4] Naveen Kumar Suniya presented a simulation modeling and shown various factors affected to system utilization and throughput. [5] Nidhish Mathew and R. Saravanan developed a procedure based on the non-dominated sorting Genetic Algorithm (NSGA-II) for 43 jobs using combined objective optimization method and made comparison between the proposed NSGA-II and other algorithms like SPT, PSO, GA, CS and obtained result for 80 jobs problem with existing NSGA-II result and found computational effort is 50% less than the traditional NSGA-II.

[6] M. Abbas and W.A. Khan studied the effect of scheduling rules as Longest Processing Time, Shortest Processing Time, Johnson, Gupta and Palmer on job shop scheduling and proposed a new heuristics called "Weighted index (WI)" which gives favorable results compared to the mentioned rules. It also has less computational charge compared other heuristics. [7] ANKUR S. VASAVA presented work for simultaneous scheduling of machines and AGVs in FMS to minimize the make span using genetic algorithm(GA). The coding of the proposed system has been done using MATLAB software and found result similar to

the operation based method. [8] Arshad Milana and Khurshid discuseed the effect of scheduling rules for three layouts and five machines modeled in ARENA and proved the effect of the FMS layouts was marginal in case of in-line and double-line FMS compared to performance of loop layout conveyed the scheduling rules effect as higher. [9] T. Ravi R.S. Lashkari and S.P. Dutta developed a simulation model for addressing the scheduling problems in FMS and demonstrated the process to select an appropriate scheduling rule for evaluating the various effects of resources in the system. [10] Dr. Gamal M. Nawara and Wael S. Hassanein solved the job-shop scheduling problem modeled in Arena for simulation program and found the optimal solutions in reasonable times. [11] Pandey R and Singh A obtained the graph before and after introducing of AGV in the system and plotted percentage utilization of AGVs and machines in FMS environment concluded that job production was improved with increase in efficiency of the whole system. [12] Reddy B.S.P. and Rao C.S.P. analyzed a flexible manufacturing system using Automod and considered both machine & vehicle scheduling and observed that assignment rule of At vehicle performance, bi-directional paths for FCFS rule and unidirectional paths for machine sequence for LPT rule found to be better with vehicle utilization and increase in the make span. [13] J. Jerald, P. Asokan, G. Prabaharan and R. Saravanan developed the optimization procedures by using non-traditional approaches and successfully implemented for scheduling optimization problem of FMS results was plotted for 3 distinct set of jobs and machines as 10 jobs 8 machines, 20 jobs 15 machines and 43 jobs 16 machines and found that Particle swarm algorithm is finer for the least collective objective function. [14] Gaurav Kumar and Trilok Singh Bisoniya used genetic algorithm to minimize the make span for the job shop scheduling optimization and coded the algorithm in MATLAB. [15] E. Aanen, G.J. Gaalman and W.M. Nawijn described a scheduling/planning come close to FMS with hierarchical structure to produce variety of parts in small batches.

3. FMS Modeling and Simulation Using Arena

Arena the discrete-event simulation package is used for modelling and simulation is capable to produce wide variety of experiment model. The modules are used to build the models which represent process or logic to perform specific task. It can resemble the model in real time environment due to its high automation capability. The simulation environment is built by giving attributes to module describing the movement of AGV and at preceding the model is run to produce real time routine characteristic of the structure. The simulation model is capable to vary the replication length to obtain optimum result for the given problem.

3.1 Problem Description

These flexible manufacturing systems (FMS) are composed of 3 machining centers and 1 load and unload station. The material handling of the system is done by using automatic guided vehicles. The loading or unloading of part is done at load/unload station then the part type is moved by AGV to the machining centre. A part type has to be processed according to the fixed process routings and part mix ratios shown in table 1. The velocity of the vehicle is 10 m/min and the load time is equal to the unloading time which is equal to 4 min. The distances are given in meters. The considered FMS layout is shown in figure 1.

Table 1: Routings and part mix ratios.

Part type	Routings	Part mix ratio
A	MC1, MC3	30%
B	MC2, MC1	10%
C	MC2 (1ST SETUP) MC2(2ND SETUP)	60%

The arrival time of parts to the system is exponentially distributed with parameter 1/12. For the given high level of automation, all the processing times are deterministic with values reported on table 2. The objective is to schedule parts on machine to obtain effective utilization of machines & AGV with overall system utilization.

Table 2: Processing times (min)

Part type	MC1	MC2	MC3
A	20	-	30
B	6	24	-
C	-	1st Setup:10 2nd Setup:6	-

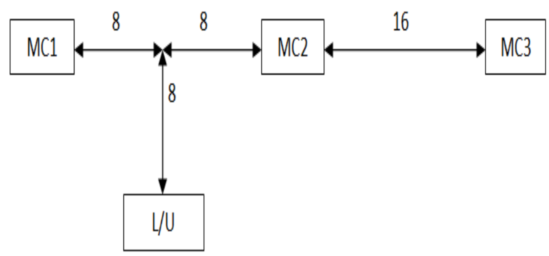

Fig.1: FMS layout

The following assumptions have been made for the scheduling of parts for simulation modeling in Arena:
1. Tool supervision is not considered i.e. tools arrangement is done prior to scheduling.
2. All part types are ready to be processed at time zero.
3. Only one part type can be processed on every machine for a mentioned era of time.
4. Each job visits machine according to their mentioned part routings only.
5. Continuous availability of machines is taken into account.
6. There is only one machine kind of its identical type. So no similar machines are considered.
7. No pre assumption of operations on machines is allowed.
8. The hauling time is neglected between different machining centers.
9. The setup times for the three dissimilar part types is added to the processing time.
10. The load and unload time is equal.

The above assumptions are similar to the classical Job shop scheduling problem (JSSP) which we will be using in this paper to showcase behavior of the model by Arena Software to find the output such as avg. waiting time (WI), avg. work in process (WIP), avg. queue time, resource seized, machine instantaneous utilization and scheduled utilization for multiple replication length to obtain result in half width mean.

3.2 Proposed Methodology

Now we will construct our proposed model using Arena software. The flowchart of the proposed methodology is mentioned on figure 2.The input is given to module blocks which describes about a logic or process. Primarily all the parts are accessible at load/unload station and the AGV moves the parts to the respective machines for processing based on the route sequence mentioned in problem. As initially all the machines were available at zero time First in first out criterion is followed for scheduling of parts on the machines. As soon as the parts complete it's processing on machine it moves on to AGV for next preceding operation.

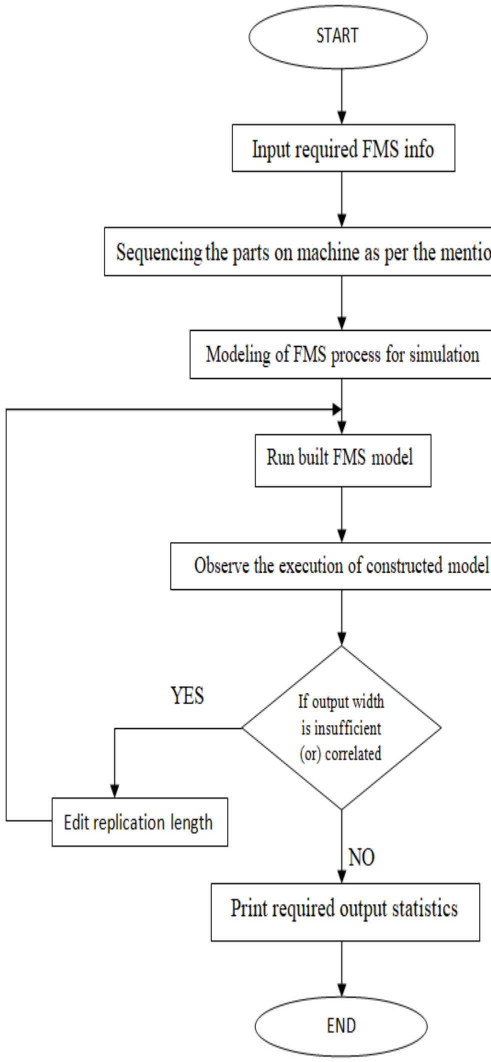

Fig. 2: Flowchart for proposed methodology

The model is developed into 3 phases:
Phase one: It will define all the variables and attributes such as entities, queues, expressions, distances between centers, stations, allocation of the resources, initializing the sequence and release of the parts.
Phase two: In the second stage the parts are assigned to machines, creating parts and part routing is done for the operations. The machine centers and AGV behavior is defined with their attributes by using modules.
Phase three: The final stage describes about the part exit from flexible manufacturing environment and the system will compute the time of parts before it gets disposed.
The details of above three stages are discussed as follows:
Phase I: It will include the modules for creating the variables and attributes defined to perform tasks.

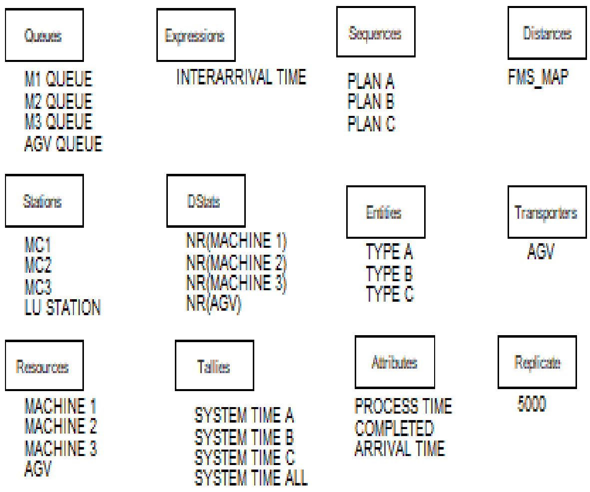

Fig.3: Phase I

The Stations element describes the total count of stations, their names, related intersections and their related activity area in our case we have considered (3) machine stations and (1) load/unload station. Entities block is used for defining the entity types we have taken (3) parts as entity. The Resources element speaks about the resource names and their capacity which represents identical units of resource name available. The element Queue specifies the number of queues along with their names, ranking criterion in our case we taken FIFO as ranking criterion. The Expressions module used to define logic or user defined system variables in Arena we have defined the exponential variable with 1/12 and interarrival time. DSTATS element used to obtain time-persistent statistics in system which we have obtained for (3) machines and AGV. Tallies blocks refer individual tallies by the number or name described in the element i.e. computed system time for all the parts and overall system time. Sequences module is used to define and ordered set of stations that parts visit for static assignments made for each stations in the part sequence here the NS describes sequence set number to use. Attributes element used in the model by their name or attribute array A(k) where k is computed as index. In this model we have considered (3) attributes as process time for parts, parts completion time and arrival time. Distances module used to specify the distance between stations which is described in problem. Transporters element used for establishing path for carrier here we have used free path which will not influence the AGV path and moves freely. Final module replicate used to run the setup for the simulation replication length required to obtain statistics.
Phase II: It includes all the modules required to create, assign the part types and routing of the parts for machining.

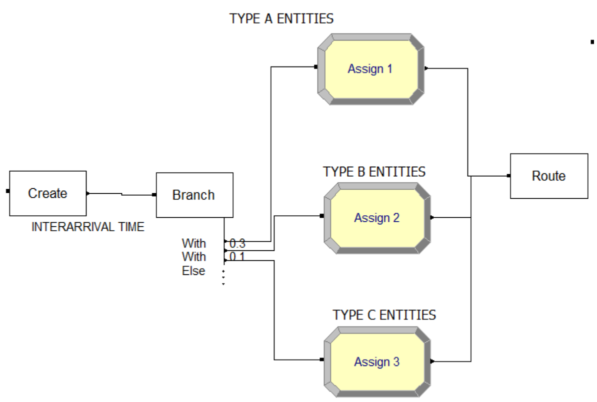

Fig.4: Phase II

Create module from blocks generates arriving entities to a processing model. The arrival time of parts in the proposed model uses interarrival time. Branch block controls the flow of parts through set of branches as part mix ratio for type A entities is 30% it will process the parts with probability of 0.3 similar to the type B with 0.1 probability and rest for the type c entities i.e. 60% with remaining probability as 0.6. Assign module from basic process used for allocating new values to variables, entity attributes and types etc. The route module from blocks transfers the entity of part types in mentioned time to the station. Machine centers behavior is described by using various modules in figure 5.

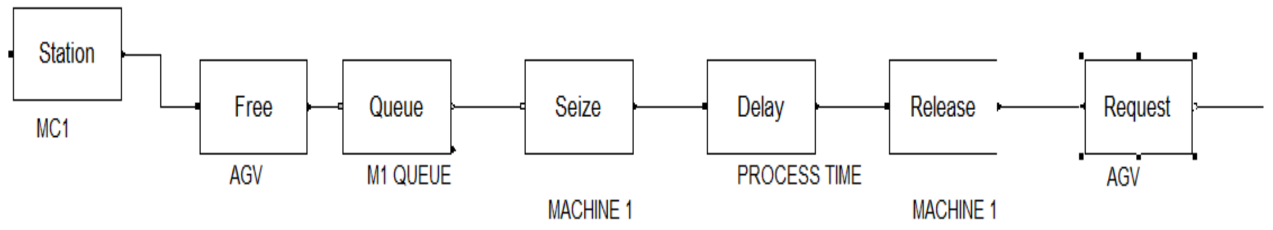

Fig. 5: Machine behavior

The parts goes to station machine1 by the AGV from that parts moves to buffer unit for machining the queue module either stores the part or process to machine for operation. The seize element allocates the resource and process the entity type for creation of part. Delay module is used to delays entity which is the processing time and there after the entity is released and requested for carrier AGV to carry the processed part for further operation or to dispose. Similarly, machine centers 2 and 3 behave in similar fashion like machine centre 1.

The AGV behavior is described using figure 6.

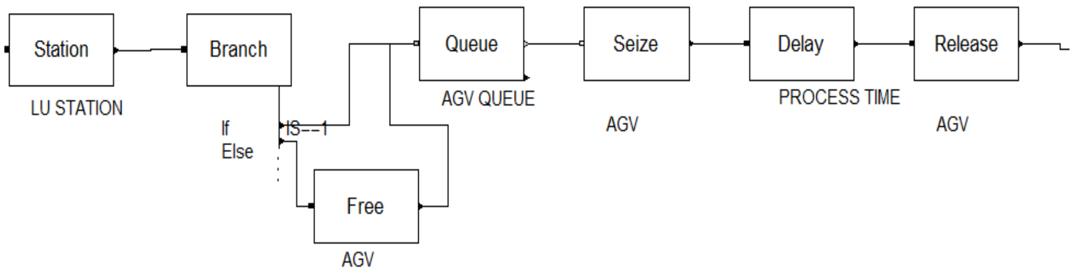

Fig.6: AGV behavior

The parts are stored at Load/Unload station the branch module controls the parts. If condition is==1 then parts are queued in station else the AGV is free and moved the entity to seize the parts and waits until it process then AGV release the parts from machine centre to the load/unload station.

Phase III: The following figure indicates the final stage that is computing time for all the system before disposing of the parts is done from manufacturing system.

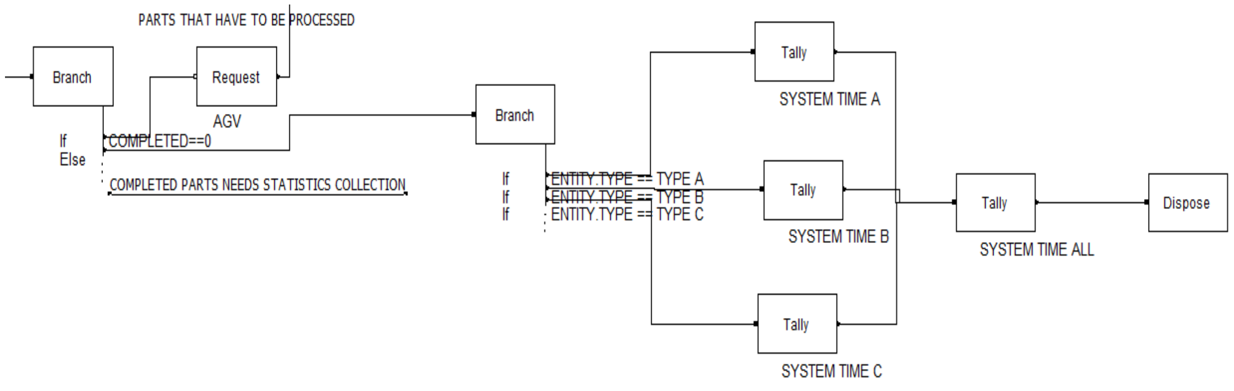

Fig. 7: Dispose of parts and computation of system time

The completed parts moved to Load/Unload station from there it is sorted using branch module and then their respective time is computed according to the entity type by using tally module. The computed entity type is then disposed to inventory or moved out of the manufacturing industry.

4. Results and Discussion

Simulation studies are performed on the given FMS layout model arrangements. The following results have been obtained for the scheduling problem by using discrete event simulation. The FMS layout considered in this study is taken from the web source and the procedure is developed for 3parts and 1AGV using simulation method.

Table 3: Work in process statistics for different replication length

Replication Length	5000 minutes		10000 minutes		15000 minutes		20000 minutes		25000 minutes		30000 minutes	
Entity type	**Avg.**	**Half Width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half Width**	**Avg.**	**Half width**
Type A	2.9363	Insufficient	3.8336	Correlated	3.8126	Correlated	3.4385	correlated	3.6091	0.72980824	3.3817	Correlated
Type B	0.611	Insufficient	0.7827	Insufficient	0.7359	Insufficient	0.7680	0.148647506	0.8187	0.18297462	0.8189	0.152273347
Type C	3.6545	Correlated	3.5947	0.58956323	4.0875	0.82552738	4.4412	0.797322188	4.3745	0.81090426	4.4261	0.723455598

Table 4: Avg. Waiting time statistics of the machines queue and AGV queue

Replication Length	5000 minutes		10000 minutes		15000 minutes		20000 minutes		25000 minutes		30000 minutes	
Queue	**Avg.**	**Half Width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half Width**	**Avg.**	**Half Width**	**Avg.**	**Half width**
M1 Queue	13.835	Insufficient	22.1689	6.85945	24.2350	6.55806	22.1624	5.77481	26.765	8.88491	24.789	7.62132
M2 Queue	15.391	Correlated	14.8093	4.21872	18.3655	Correlated	21.3907	6.50188	21.532	7.06876	22.06	6.10665
M3 Queue	26.515	Insufficient	43.7738	Insufficient	40.6408	17.69717	34.3554	Correlated	34.335	14.91708	31.069	12.83488
AGV Queue	0.6537	0.0932282	0.6180	0.0663762	0.6331	0.07388	0.6335	0.0657885	0.6239	0.054265	0.6488	0.0604614

Table 5: Avg. number of parts waiting

Replication Length	5000 minutes		10000 minutes		15000 minutes		20000 minutes		25000 minutes		30000 minutes	
Station	**Avg.**	**Half Width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half Width**	**Avg.**	**Half width**
M1	0.4645	Insufficient	0.8060	0.2737316	0.8570	0.2699228	0.7613	0.2125025	0.9293	0.331928	0.8480	Correlated
M2	1.6186	Correlated	1.5375	0.4830473	1.9474	0.7472279	2.3158	0.7425238	2.2919	0.778075	2.3511	0.684215
M3	0.6735	Insufficient	1.1863	Correlated	1.0969	Correlated	0.8898	Correlated	0.9051	0.446588	0.7982	0.378084651
AGV	0.1355	0.023223577	0.1323	0.0162098	0.1374	0.016294	0.1379	0.0162843	0.1351	0.014448	0.1398	0.014874826

Table 6: Instantaneous utilization of machines and AGV

Replication Length	5000 minutes		10000 minutes		15000 minutes		20000 minutes		25000 minutes		30000 minutes	
Station	**Avg.**	**Half Width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half width**	**Avg.**	**Half Width**	**Avg.**	**Half width**
M1	0.6976	Insufficient	0.7531	Insufficient	0.7393	Insufficient	0.7206	0.0444129	0.7278	0.049796	0.7168	0.042858849
M2	0.7968	Insufficient	0.8101	0.0528028	0.8300	0.0480110	0.8440	0.0394676	0.8348	0.033577	0.8358	0.032149914
M3	0.7590	Insufficient	0.8118	Insufficient	0.8063	Insufficient	0.7770	Insufficient	0.7908	Correlated	0.771	Correlated
AGV	0.5080	0.034326286	0.5228	0.0257337	0.5317	0.025083	0.5348	0.020720	0.5310	0.018716	0.5292	0.018359480

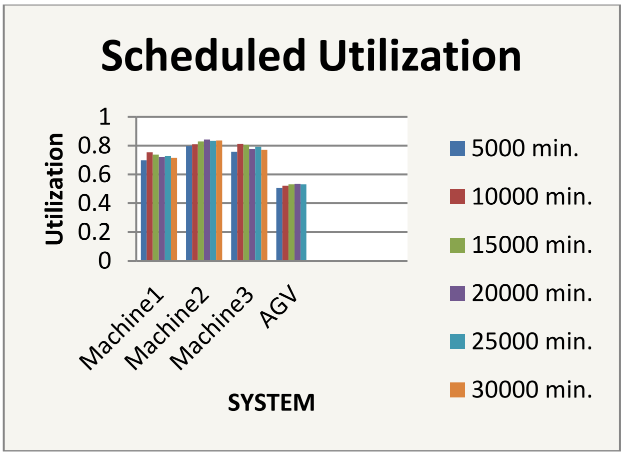

Fig.8: Comparison for scheduled utilization of system

A comparison is made for the scheduled utilization in Fig.8 and the number of resources seized in Fig.9 for all the machines and AGV with different replication length to match confidence interval of Arena's half width. Among the 6 simulation replication length the 25000 minutes simulation run found to be in confidence interval i.e., 95% of trials reported as within the interval sample mean.

5. Conclusion

The purpose of this study is to present methodology to compute effective utilization of machines and AGV in flexible manufacturing system by means of Arena and considered both machine and vehicle scheduling to observe their behavior in the given environment. It is observed that 25000 minutes replication length produced almost nearest mean values for work in process, average waiting time and average number of parts waiting and for the rest either it is insufficient or correlated which indicates inadequate number of samples for computation. The machine 2 scheduled utilization percentage is found to be more compared to other system. It is observed that number of resource seized was increasing for the different replication length. The AGV utilization in both case of scheduled and instantaneous measure is found to be nearly equal for the various lengths. Further research may be carried out for other types of routing to evaluate their performance as the simulation result may differ due to runtime.

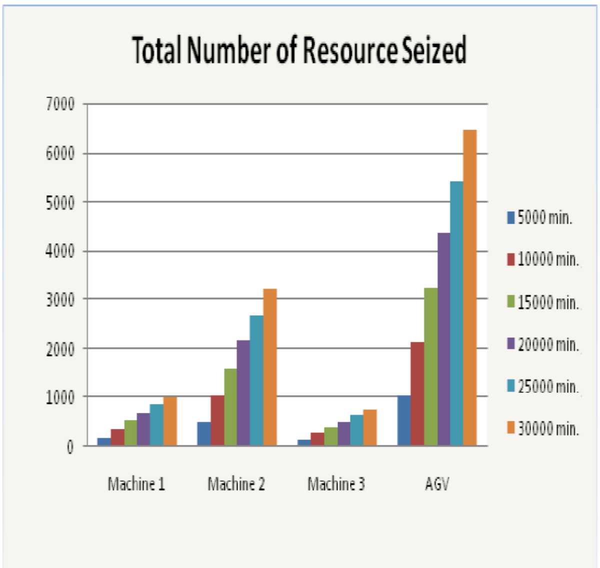

Fig.9: Comparison for resource seized

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