Scheduling of Three FMS Layouts Using Four Scheduling Rules

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Abstract: **This paper presents the scheduling of Flexible Manufacturing System (FMS) using discrete event simulation. Simulation models have been developed using Arena, for three basic FMS layouts and four scheduling rules: First-Come-First-Serve (FCFS), Shortest Processing Time (SPT), Longest Processing Time (LPT) and Earliest Due Date (EDD). Automatic Guided Vehicles (AGVs) are used as the Material Handling System (MTH) in the system. The scheduling rules in each of the individual FMS layouts are evaluated and compared in relation to five output measures: number of products being produced, average machine utilization, mean flow times, mean queues and mean tardiness. The simulation results are analyzed and discussed in detail and conclusions have been drawn on scheduling rules that yield best results in given scenarios, with the SPT rule performing the best (LPT being the worst). The more important result shows that the effect of the scheduling rules have much greater impact on the output performance measures than the differing FMS layouts.**

Keywords: Flexible Manufacturing Systems (FMS) Layouts, Scheduling Rules (FCFS, SPT, LPT, EDD), Automatic Guided Vehicles (AGVs), discrete-Event Simulation, Arena Software.

I. INTRODUCTION

FMS is highly automated complex system consisting of several Computer Numerical Controls (CNC) machines, material handling systems and human operators. The scheduling of FMS is very complex and needs proper planning to achieve high efficiency, shortest production time and low inventory due to its processing of wide variety of parts simultaneously. Computer simulation can be a valuable tool in order to cope with the scheduling of FMS (1). Simulation is a powerful tool which attempts to imitate the behaviour of real system overtime and draw inferences about its performance. It is used to study various strategies and plans and gives the result of each strategy individually so that a best solution for a given problem can be found. Hence simulation helps in decision making for optimum solution and is used as a tool for Decision Support System (DSS) for scheduling of real world manufacturing system (2).
The aim of this paper is to present three (discrete event) simulation models of “In-Line”, “Double Line” and “Loop layout” for FMS in which ten jobs are processed on different machines using Automated Guided Vehicles (AGVs) as transporters for the complete analysis of four most used scheduling rules: First Come First Serve (FCFS), Shortest Processing Time (SPT), Longest Processing Time (LPT) and Earliest Due Date (EDD). This is to study the effect of the FMS layout and different scheduling rules on the output measure.

II. FLEXIBLE MANUFACTURING SYSTEMS (FMS)

There many ways to define an FMS. Groover (3) defines it as an automated Group Technology (GT) machine cell, consisting of a group of processing workstations (e.g. CNC machines), inter-connected by an automatic materials handling and storage system and where a distributing computer system controls the process. FMS is called ‘flexible’ because it’s able to process a range of different parts at different work-stations simultaneously, and the different styles and production quantities can be adjusted to the change in demands.

According to (4), an FMS is a group of production tools logically organized via a host computer system and connected by a vital transport system. The main objective of it is being able to simultaneously produce a mix of product part styles whilst also flexible enough to consecutively produce a different mix of part types without high cost, time-consumption and the change-over requirements for different combinations. Thus the aim of FMS technology is to bring together two conflicting objectives necessary for manufacturing organization working in flexible environment i.e. to obtain high through put and capacity utilization with less Work in Process (WIP) and to achieve high efficiency with flexibility (product demand and mix).

A. FMS Layouts

According to (4), the layout configurations found in modern FMSs can be divided in to five categories i.e.

- In line layout
- Loop layout
- Ladder layout
- Robot centered layout
- Open field layout

In In-line layout, machines and handling systems laid out in straight lines as shown below in Fig.1. Parts are transported from workstations in an orderly fashion. There is no backward movement; parts only flow in forward direction. The functionality of the In-line layout is not very different to transfer line. Back flow of work in the system can be implemented by the flexibility of material handling system. A way of having this possibility is that a secondary part handling system is incorporated to every workstation this is used to split parts from the primary line of work. Double-line layout is the same as in-line layout except that the machines are placed on both sides of transfer line as shown in Fig. 2.

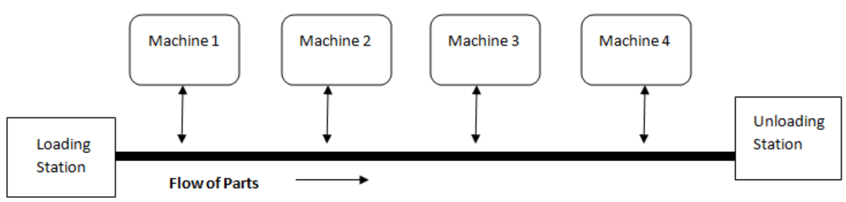

Fig.1: In-Line Layout

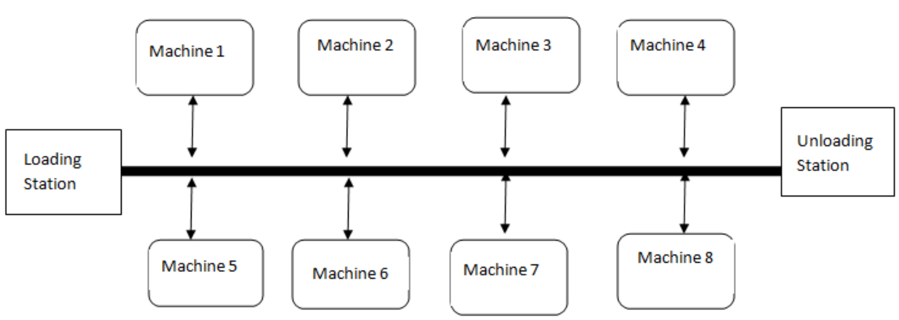

Fig. 2: Double Line Layout of FMS

In the basic Loop layout as shown in Fig. 3, parts are moved in one forward flow around the loop. It enables the user to stop at any point of production. The load and unload stations are usually placed at an end of the loop. Once again each station accommodates a secondary handling system to ensure smooth flow and no interruption of flow around the loop.

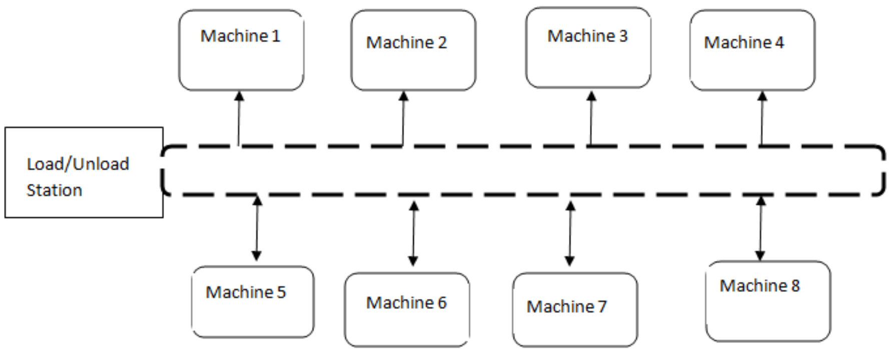

Fig. 3: Loop Layout of FMS

The ladder layout is made up of the basic loop configuration incorporated with rungs of work stations. The rungs are located on sections of the loop and are used to increase transportability and routes that parts go through. This reduces traffic and time taken to transport parts from one station to the next.
A Robot-centered configuration utilizes one plus robots as material handling systems as shown in Fig. 4. The robots can be provided with grippers which help with handling of parts, especially rotational ones. This configuration of layout is usually used to process cylindrical or circular shaped parts.

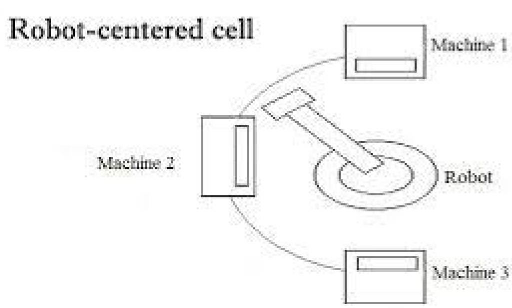

Fig. 4: Robot-Centered Layout of FMS

III. PROPOSED FMS MODEL LAYOUTS

Simulation models developed in this study are based on the modification of the research carried out by (5) for scheduling in FMS. Each model processes ten part types with each part having its own sequence of operation and processing time on five different machining centers. Only one part type can be processed at a time. Each part visits each machine only once and single machine is available for each machine type. Machine break down and repair time is not considered in the study which means that all machines are available continuously all the time. The due date for each part type is known. The machines setup time for each part type are included in the processing time of each operation. AGVs are used as transporter in the system for moving the job from Enter/Exit station due to their concerned work station for processing and move to another work station after completed processing. AGV search the job to transport within the system, pick-up the job and drop off at their concerned station. The transportation time is determined by the distance between the station and speed of AGV. The speed of AGV is 50 meter per minute. The processing time along with the sequence of operation for each part type on machines is given in Table 1. The machines are placed in different arrangements which lead to the formation of three layouts. The distances in meters from the Enter/Exit station and within the machines for each of the above mentioned layouts are presented in Tables 2, 3 and 4.

Part Types	**Machines (Mean Processing Time)**					**Total Processing Time (minutes)**
1	M2 (8)	M1 (11)	M5 (12)	M4 (10)	M3 (13)	54
2	M1 (21)	M4 (12)	M5 (6)	M3 (9)	M2 (7)	55
3	M4 (9)	M5 (13)	M2 (12)	M3 (7)	M1 (8)	49
4	M2 (7)	M1 (13)	M5 (9)	M3 (6)	M4 (12)	47
5	M1 (13)	M4 (9)	M3 (10)	M2 (14)	M5 (11)	57
6	M2 (12)	M3 (10)	M5 (9)	M1 (7)	M4 (8)	46
7	M4 (8)	M5 (15)	M2 (16)	M3 (14)	M1 (8)	61
8	M3 (13)	M1 (9)	M2 (14)	M4 (6)	M5 (8)	50
9	M4 (7)	M2 (13)	M5 (9)	M1 (18)	M3 (12)	59
10	M5 (10)	M2 (8)	M3 (15)	M2 (11)	M1 (12)	56

Table 1: Machine Sequence and Process Time

	To						
From	**Order Release Station**	**Cell 1**	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**	**Exit Station**
Order Release Station	_	5	10	15	20	25	30
Cell 1	5	-	5	10	15	20	25
Cell 2	10	5	-	5	10	15	20
Cell 3	15	10	5	-	5	10	15
Cell 4	20	15	10	5	-	5	10
Cell 5	25	20	15	10	5	-	5
Exit Station	30	25	20	15	10	5	-

Table 2: Distances in Single Row Layout

	To						
From	**Order Release Station**	**Cell 1**	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**	**Exit Station**
Order Release Station	_	5	10	15	15	10	30
Cell 1	5	-	5	10	20	15	15
Cell 2	10	5	-	5	15	20	10
Cell 3	15	10	5	-	10	15	5
Cell 4	25	20	15	10	-	5	5
Cell 5	10	15	20	15	5	-	10
Exit Station	30	15	10	5	5	10	-

Table 3: Distances in Double Row Layout

	To						
From	**Order Release Station**	**Cell 1**	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**	**Exit Station**
Order Release Station	_	5	10	15	20	25	0
Cell 1	5	-	5	10	15	20	25
Cell 2	10	5	-	5	10	15	20
Cell 3	15	10	5	-	5	10	15
Cell 4	20	15	10	5	-	5	10
Cell 5	25	20	15	10	5	-	5
Exit Station	0	25	20	15	5	5	-

Table 4: Distances in Loop Layout

B: FSM Scheduling

An FMS is made up of an extensive amount of interacting hardware and software components. Some problems in FMS can be because of factors such as handling of production orders, poor organization of parts routing and sequencing, machine scheduling and the administering of system performance and corrective action. The scheduling goal is to assign orders on different machines for product manufacturing involving various conditions (7). FMS widely follow dispatching rules for the scheduling of parts and machines. Once a machining center completes a part almost, instantaneously it gets allocated a job from its input queue for setup and processing. This is known as dispatching (8). They are many different ways to classify dispatching rules. According to (9), dispatching rules can be put under two main categories known as static and dynamic rules. Static rules do not depend on time and remain the same as the job move through the plant. An example of a static rule would be Shortest Processing Time (SPT). However, dynamic rules change depending on time and queue characteristics (9).

Dispatching rules can also be classified on the basis of information they are established from. For example local heuristic rule uses information associated with queue where part is waiting or the machine where part is being queued (10). Global rule also needs information on other machinery like the time taken to process the job on upcoming machinery of a jobs sequence. SPT and FCFS can be seen as local rules (11). The following heuristic rules were chosen for this paper:

FCFS: According to FCFS, jobs are processed in sequence according to the order in which they enter the system. This is the most common dispatching rule in which the job on the top of the queue don't have to wait for longer time and is picked up first by machine for processing.

SPT: In SPT rule, the jobs are processed according to increasing order of their processing time i.e. the job with the minimum processing time is picked up first by the machine and then followed by the job with the second minimum time and so on. This rule tends to optimize the average lateness and flow time of the job. The opposite of it is another dispatching rules i.e. LPT, in which the job with the longest processing time is served first in the machine and then followed by others.

LPT: This is the opposite of SPT: in the LPT rule, the jobs are processed according to decreasing order of their processing time i.e. the job with the maximum processing time is picked up first by the machine and then followed by the job with the second minimum time and so on.

EDD: In EDD, the jobs are processed according to their due dates. The sequence for processing of job is developed on the basis of increasing order of their due dates i.e. the one whose due date is early, is served first by machine and then followed by next earliest due date. This rule aims to minimize tardiness and lateness.

IV. MODEL VERIFICATION AND RESULTS

Simulation models developed in this study are based on the modification of the research carried out by (5) for scheduling in FMS. Each model processes ten part types with each part having its own sequence of operation and processing time on five different machining centers. Only one part type can be processed at a time. Each part visits each machine only once and single machine is available for each machine type. Machine break down and repair time are not considered in the study which means that all machines are available continuously all the time. The due date for each part type is known. The machines setup time for each part type are included in the processing time of each operation. AGVs are used as transporter in the system for moving the job from Enter/Exit station due to their concerned work station for processing and move to another work station after completed processing. AGV search the job to transport within the system, pick-up the job and drop off at their concerned station. The transportation time is determined by the distance between the station and speed of AGV. The speed of AGV is 50 meter per minute. The processing time along with the sequence of operation for each part type on machines is given in Table 1 (above). The machines are placed in different arrangements which lead to the formation of three layouts.

One important point which should be kept in mind while working on simulation models that they use random variates from probability distribution of input data which gives random output and makes the result less precise. There are several methods for dealing with this problem of randomness. Among them, the common one is to minimize the confidence interval half-width by increasing the number of replications to reduce randomness in the results. But this method leads to more simulation work and time which makes it less effective. Another method is the use of "seed" function for fixed random number generation to avoid the inherent randomness from affecting the results.

In order to have analysis of different scheduling rules and the FMS layouts in developed model, it is necessary to reduce various sources of randomness for the arrival times, processing times and transportation times. This was achieved by providing the same stream of random numbers through all the alternatives where the difference between the alternatives and each replication is only based on the changes made to the model. These streams are assigned with fixed value of seeds in the "variable" module so that each alternative used the same value of seed in their replications.
The Figs. 5 to 9 below show the results of the simulations (for the three FMS layouts and the four scheduling rules), each being done with 20 replications per simulation. The key measured output parameters were: Total Production, Mean Flow Time, Mean Machine Utilisation, Mean Queue in System and Mean Tardiness.

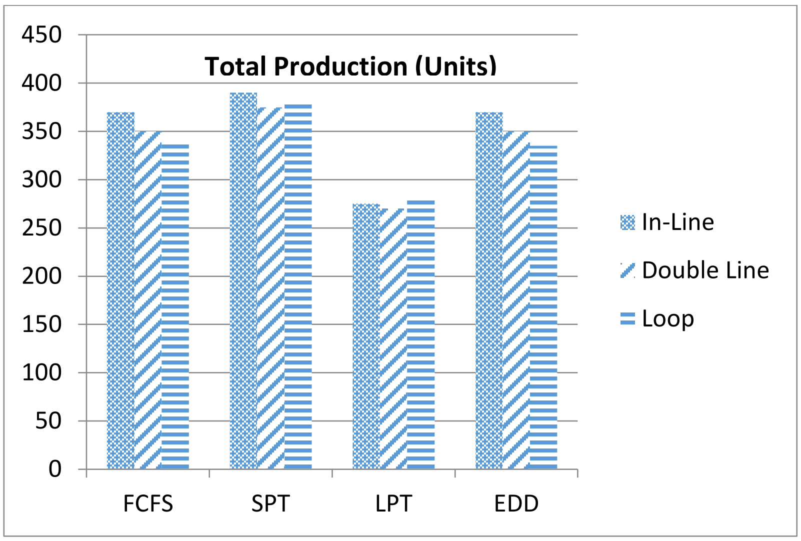

Fig. 5: Summary Results for Total Production for the three FMS Layouts and Four Scheduling Rules

As can be seen from Fig. 5, the highest production rate was achieved the SPT rule followed closely by the FCFS and the EDD rules. The worst performing rule was the LPT. In all cases, the production rate was affected more by the scheduling rules than the FMS layout, (where generally the in-line layout performed marginally better than the other two layouts).

Fig. 6 shows the Mean Flow Times for the same scenarios. As you would expect, the best performing scheduling rule was the SPT which had the a mean value of ~200 minutes, compared with the worst SPT rule (~800 minutes). The FCFS and EDD rules had ~400 and ~600 minutes, respectively. Again, the difference between the three FMS layouts, for each of the four scheduling rules was not that significant, with the double-line layout performing relatively better.

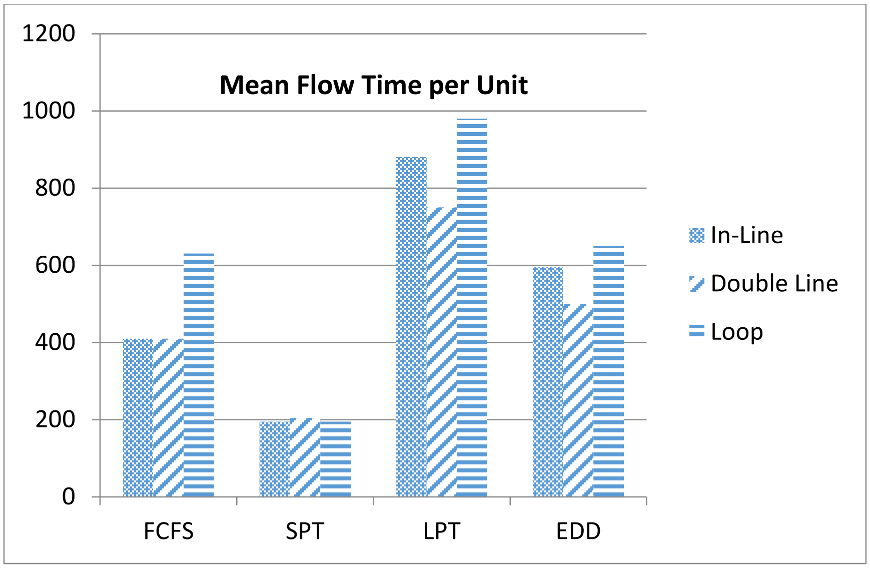

Fig. 6: Summary Results for Mean Flow Times for the three FMS Layouts and Four Scheduling Rules

These results are also reflected in the Mean Machine Utilisation (Fig.7) and Mean Queue (Fig.8) and Mean Tardiness (Fig. 9) output measures. In all cases, the effect of the scheduling rule has more of an impact on the output performance measures than the different FMS Layouts. In addition, the best performing scheduling rule is the SPT rule, with the worst performing being the LPT one. However, for the Mean Tardiness measure, the FCFS and EDD rule perform slightly better than the SPT one.

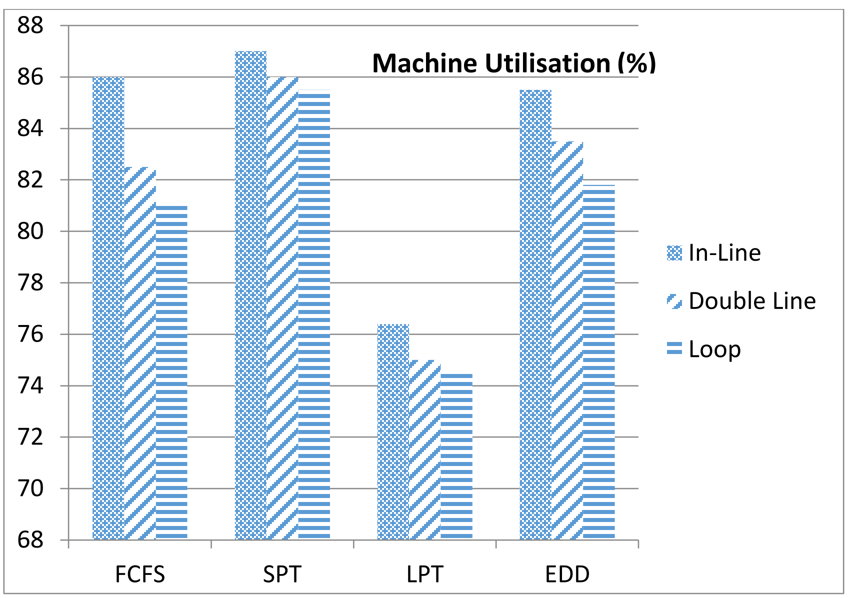

Fig. 7: Summary Results for Mean Machine Utilisations for the three FMS Layouts and Four Scheduling Rules

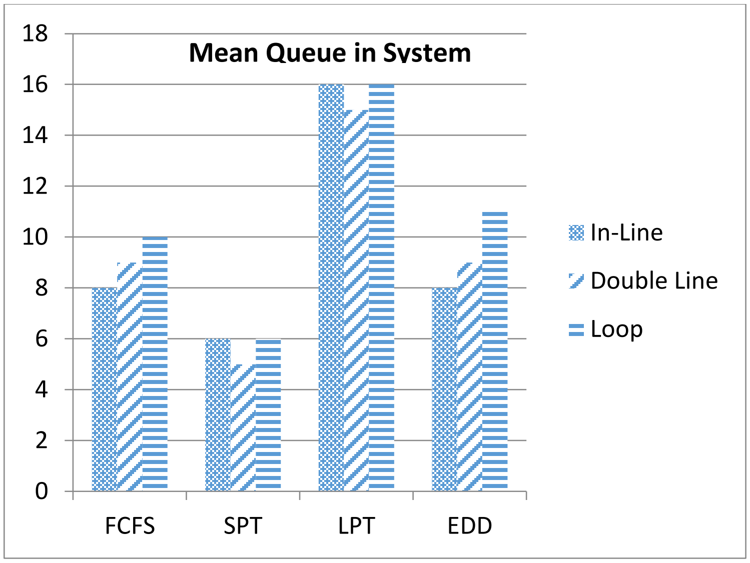

Fig. 8: Summary Results for Mean Queues for the Three FMS Layouts and Four Scheduling Rules

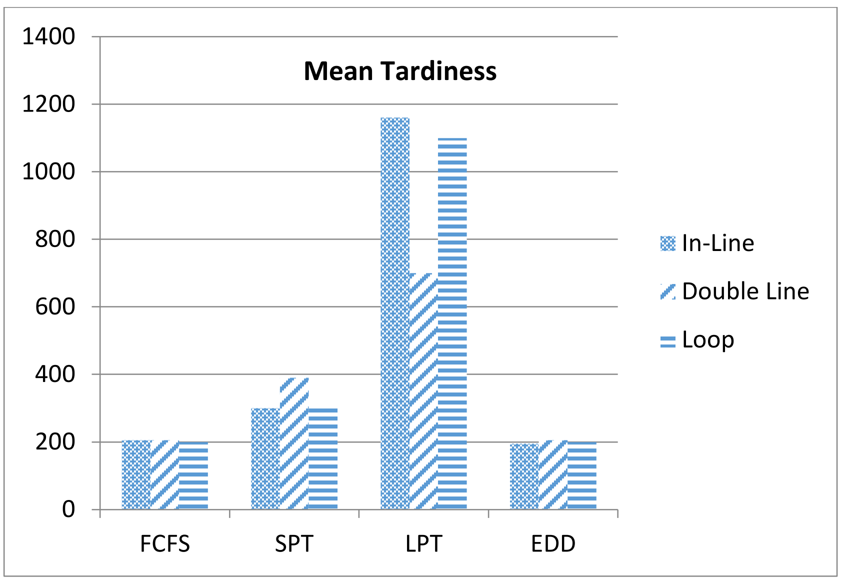

Fig. 9: Summary Results for Mean Tardiness for the Three FMS Layouts and Four Scheduling Rules

V. CONCLUSION

This paper has considered the effect of four scheduling rules and three layouts on a five machine FMS/ten product scenario using Arena, a discrete –event simulation software. A number of models were built and run using the various scenarios. It was ensured that the effect of the inherent random variation within Arena was eliminated using the seeding function so that only the effect of the differing scheduling rules and FMS layouts was being measured. It was found that, for all cases, the effect of the scheduling rules was greater than the FMS layout on the five output performance measures. The effect of the FMS layouts marginally affected the output measures, with the in-line and double-line FMS layouts performing relatively better than the loop layout. For future work, it is recommended that additional heuristic rules are simulated.

REFERENCES

[1] Cheng, H., and Chan, D., (2011) 'Simulation optimization of part input sequence in a flexible manufacturing system.' *In proceedings of the 2011 winter simulation conference,* vol. 2011. IEEE, pp. 2369-2377.

[2] Kelton, W. D., Sadowski, R. P., Sturrock, D. T., (2007) *Simulation With Arena.* 4th, Boston: McGraw Hill Higher Education.

[3] Groover, M. P., (2001) *Automation, Production Systems, and Computer-Integrated Manufacturing.* edn. Prentice Hall Press.

[4] Parrish, D. J., (1990) *Flexible Manufacturing.* edn. Butterworth-Heinemann London.

[5] Reddy, B. S. P., and Rao, C. S. P., (2011) 'Flexible manufacturing systems modelling and performance evaluation using AutoMod', *International Journal of Simulation Modelling,* 10(2)**,** pp. 78-90.

[6] M K Khan, I Hussain and S Noor (2011), "A Knowledge Based Methodology for Planning and Designing of a Flexible Manufacturing System", *International Journal of Advanced Manufacturing Systems (IJAMS),* Vol. 13, Issue 1.

[7] S. Maqsood, M. K. Khan and A. S. Wood (2013), "A novel index based heuristic for job shop scheduling", *International Journal of Customer Relationship Marketing and Management (IJCRMM),* Special Issue.

[8] S. Maqsood, M. K. Khan and A. S. Wood (2012), "Hybrid Genetic Algorithm (GA) for job shop scheduling problems and its sensitivity analysis." *International Journal of Intelligent Systems Technologies and Applications (IJISTA),* Special Issue, Vol. 11, Issue1/2, pp. 3-16.

[9] Papadopoulos, H. T., and Heavey, C., (1996) 'Queueing theory in manufacturing systems analysis and design: A classification of models for production and transfer lines', *European journal of operational Research,* 92(1)**,** pp. 1-27.

[10] Conway, R. W., Maxwell, W. L., Miller, L. W., (2012) *Theory Of Scheduling.* edn. Courier Dover Publications.

[11] Pinedo, M., and Chao, X., (1999), *Operation Scheduling With Applications In Manufacturing and Services*. International edition, Irwin/Mc Graw-Hill.

BIOGRAPHY

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