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EFFECT OF MATERIAL TRANSFER STRATEGY AND MANUFACTURING FLEXIBILITY ON THE PERFORMANCE OF FMS

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Abstract - In this paper effect of material transfer strategy through automated guided vehicle on the performance of flexible manufacturing system is studied. Simulation models are developed using ARENA simulation software. Flexible manufacturing system under consideration consists of five flexible machines. Eight different types of parts are being manufactured. Different system parameters considered are fleet size of automated guided vehicles, number of pallets and position of buffer. Based on the position of buffer, two different configurations of manufacturing systems are developed. Further the impact of routing flexibility is also observed. Performance measures considered are make span time and machine utilization. After the analysis of the results, it is found that different system parameters did affect the performance of flexible manufacturing system.

Keywords: Flexible manufacturing system, automated guided vehicle, routing flexibility, make span time, simulation.

1. INTRODUCTION

Current manufacturing world demands an efficient modeling of any manufacturing system such that changing market scenario can be responded by the shop floor. Now-a-days, manufacturing business has become very competitive. Companies are looking for improved manufacturing technology and services. Customer's demand is changing rapidly. Production firms are developing strategies to produce variety of parts. Changing market scenario has led to all new era of research in manufacturing technology. Optimum use of material, information and resources are being preferred. To meet the expectation of market demand, it has now become necessary for the manufacturing firms to become flexible. By being flexible they can respond easily to the changes in product type economically. Product life is now reduced because of new advancement in technology. Because of changing customer preferences and competition, there is uncertainty in demand pattern. Introducing new part needs a change in production layout and strategies. Changing manufacturing strategies frequently is a costly affair hence operation planning, scheduling and control activities should be used judiciously. This gives rise to the idea of flexibility in manufacturing environment. The manufacturing trend is being changed from hard automation to flexible automation. A manufacturing system is evolved that can maintain the flexibility of low volume production while retaining the efficiency of high volume production. This type of system is known as flexible manufacturing system (FMS).

In this paper an attempt has been made to study the effect of different system parameters namely, Automated guided vehicle (AGV) fleet size, routing flexibility, number of pallets and position of the buffers on the performance of the flexible manufacturing system. Performance measures considered are Make Span Time (MST) and Machine Utilization. The

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

remainder of this paper is organized as follows: Section 2 describes the literature review in the area of concern. Section 3 states the problem formulation. The simulation models are developed in section 4. Section 5 presents the results and discussions, and Section 6 concludes the findings of this paper.

2. LITERATURE REVIEW

In current manufacturing systems, flexibility is a highly desired characteristic which has attracted the attention of researchers and practitioners. The significance of manufacturing flexibilities in responding quickly, efficiently and profitably to the changing needs of customers is well established in the literature (Sethi and Sethi, 1990; Upton, 1994; Chan, 2001; Ali and Wadhwa, 2005; Ali and Wadhwa, 2010; Ali, 2013). According to Adam et al. (1991), FMS can be defined as a computer controlled configuration of semi-independent workstations and a material handling system designed to efficiently manufacture more than one part type at low to medium volumes. However Garg, (2009) defines FMS as an integrated, computer-controlled manufacturing system consisting of automated material handling devices and numerically controlled tools that can simultaneously process medium-size volumes of a variety of part types. The make-span of a set of jobs in an FMS is minimized if operations are performed by more than one machine (Browne et al., 1984). The role of flexibility can be viewed as one that provides alternative decision solutions to certain discrete events, which the system should evolve (Groover, 2002). Udhayakumar et al, (2010) has studied task scheduling of AGVs in FMS. He attempted to find near optimal schedule for two AGVs based on the balanced workload and the minimum travelling time to maximize the utilization. Periera.A, (2011) has considered three, five and seven AGVs to study the performance of FMS under balancing machine workload and minimizing part movement rule. Ali and Khan (2010) have studied implementation issues of AGVs in flexible manufacturing system. Lee et al, (2009) has developed a simulation model to analyze FMS using AGVs. He used number of AGVs ranging from nine to thirteen having speed as two, four and six meters per second. His objective was to maximize throughput, minimize vehicle utilization and minimize transport congestion. Jerald et al, (2009) has considered two AGVs having speed hundred meters per minute. His focus of work was on minimizing penalty cost, minimizing machine idle time and minimizing distance travelled by AGV.

In this section a focus was made on the previous effort and direction related to the proposed work and some of the approaches have been incorporated in this paper.

3. PROBLEM FORMULATION

It has been observed that recent advances in manufacturing systems enabled companies to produce products more quickly and at a much lower cost than ever before. There has to be the maximum utilization of the available resources. Often research shows that there is scope for improvement in the performance of the manufacturing system. Keeping this in mind, this paper deals with the study of AGV fleet size, number of pallets, buffer locations and routing flexibility on the performance of flexible manufacturing system. Performance measures considered are Make Span Time (MST) and Machine Utilization. The typical manufacturing model is usually used either to predict system performance or to compare two or more system designs or configurations.

4. DEVELOPMENT OF SIMULATION MODEL

Computer simulation is a tool that has been widely used by the researchers to analyze the performance of FMS. Simulation model is developed using ARENA simulation package. ARENA is a computer simulation tool with a graphical user interface. The aim is to develop simulation models imitating manufacturing systems having uncertainties.

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

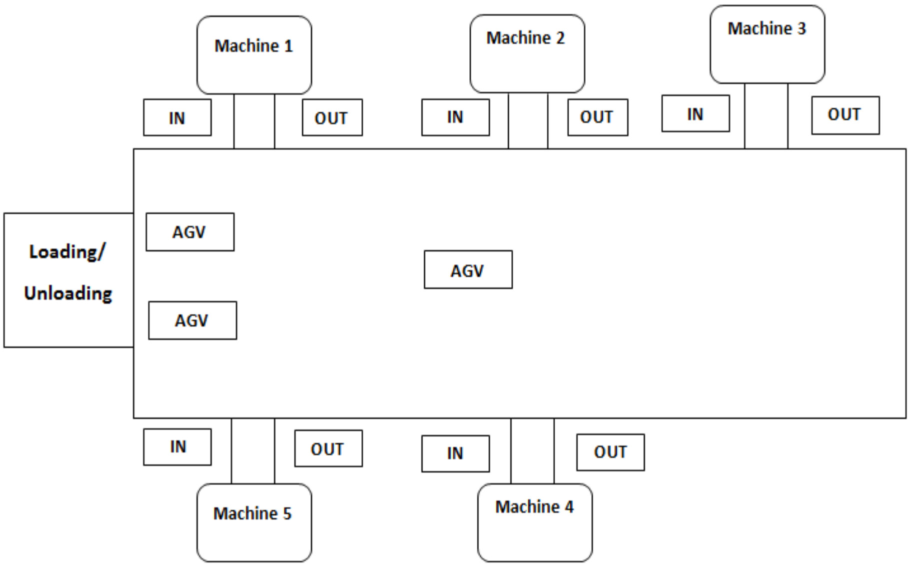

Figure 1 Layout of FMS having buffer at input and output of each machine

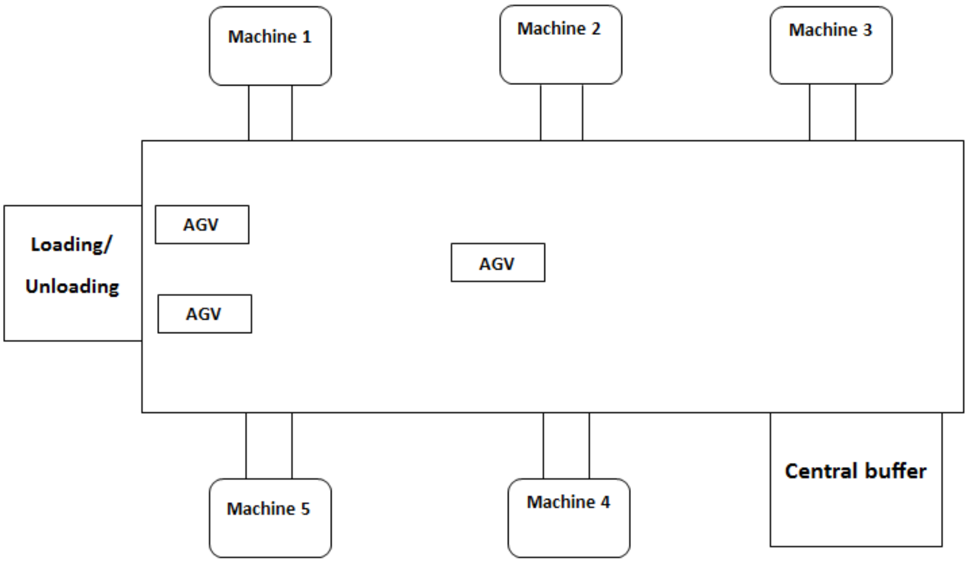

Figure 2 Layout of FMS having a central buffer

Hypothetical FMS environment is considered having five flexible machines producing eight different types of parts. Each part type has its own sequence of operations on the five machines. Parts are being moved to different machining centers with the help of AGVs. After completing the sequence of operations parts are being disposed. Performance measures like Make Span Time (MST) and machine utilization are observed after executing the ARENA simulation models.

Two different types of physical layout of the FMS as shown in figure 1 and figure 2 are considered. In one type of layout, a temporary storage buffer space for work-in-process parts are being provided at input and output of each machine. In second type of layout only one central buffer is added where all the work-in-process parts will be stored. Logic behind the operations of two systems is shown with the help of flow charts as shown in figure 3 and figure 4.

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

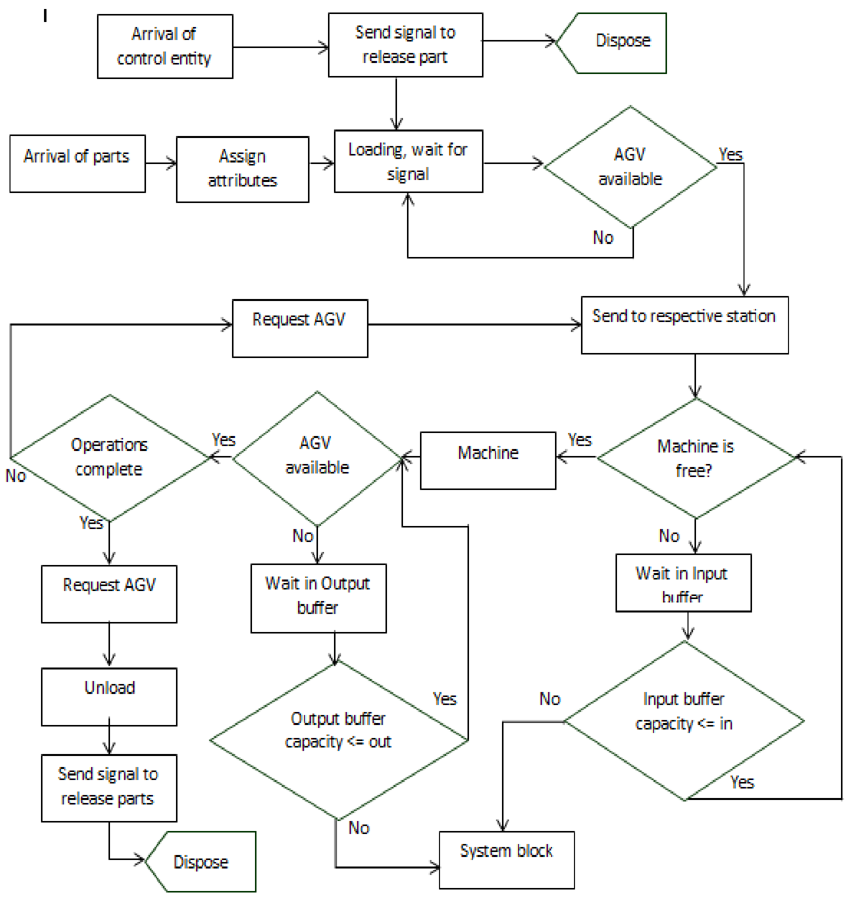

Figure 3 Flow chart of Input and output buffer model

Figure 3 is showing flow chart for In-out buffer system of FMS. Firstly, eight different parts arrives at the loading area. Here parts wait for a signal. Then parts are loaded on the pallet and then they proceed into the system. Initially control entities are created to run the simulation model. After sending the signal to release the required number of parts/pallets, the control entities are disposed of. Once the parts are released from loading area, with the help of AGV they are sent to their respective machining center according to their operation sequence. If the machine is free then part is loaded on the machine and if the machine is busy then part waits in the input buffer. As the machine become free the part is loaded on the machine and the processed part waits in the output buffer for the AGV. As the AGV becomes available the part is sent to their next machining center according to its operation sequence. For In-out buffer system input capacity of buffer is denoted by 'in' and output capacity of buffer is denoted by 'out'. Whenever the parts in the buffer at any machine exceed the buffer capacity, whole system is blocked. This cycle of process continues until a part has completed all the operations. Completely processed part is sent to unloading center with the help of AGVs and it is unloaded from the pallet. Then a signal is sent to loading area to release next part. In this way a constant number of parts/pallets in the system are maintained. Finally the finished part is disposed.

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

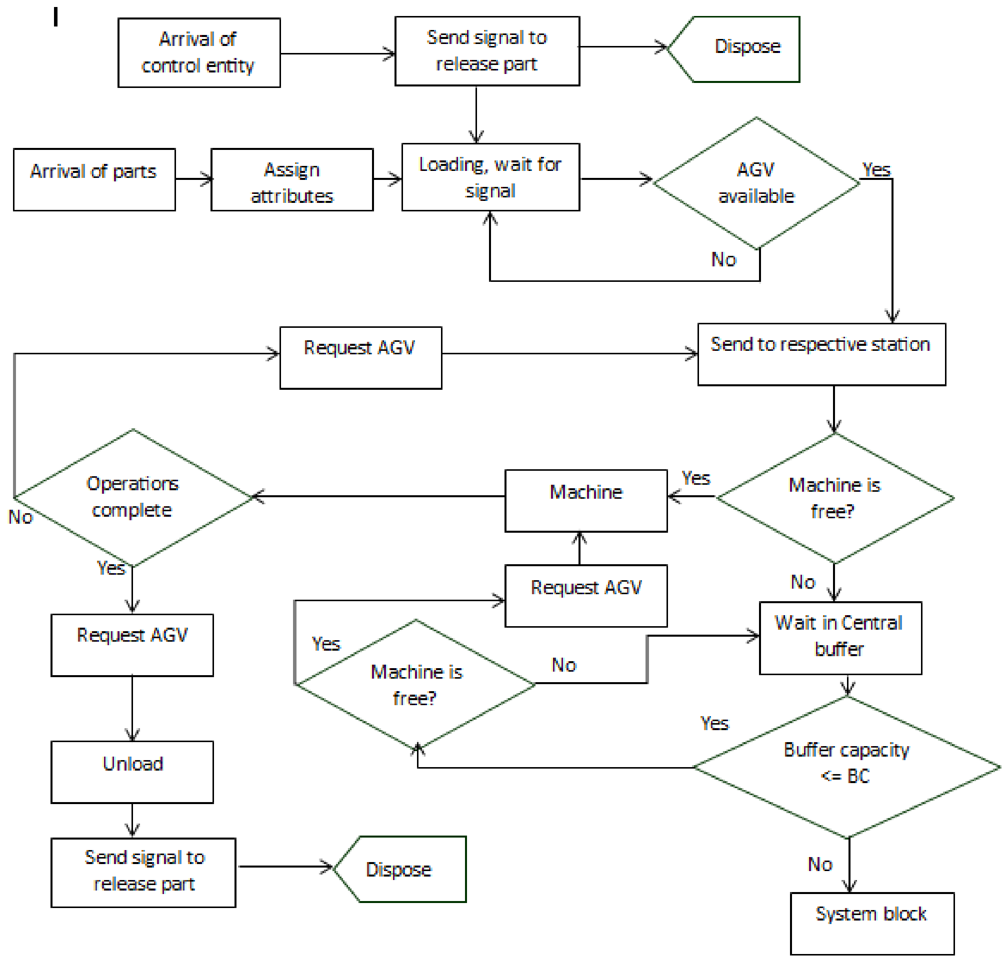

Figure 4 Flow chart of Central buffer model

Figure 4 is showing flow chart for Central buffer system of FMS. All logics are same here except that if the machine is busy, parts are being sent to Central buffer with the help of AGVs. Capacity of central buffer is denoted by 'BC'. As number of parts in central buffer exceeds the buffer capacity, system is blocked. Here routing flexibility one (RF-1) is also used to see the impact of routing flexibility on system performance. Minimum queue is used as the dispatching rule. It means parts are sent to that machining center where minimum parts in queue are present.

5. RESULTS AND DISCUSSIONS

As discussed so far, two types of system configurations based on the buffer location are studied. Simulation models based on both the system configurations are run and results are collected. Number of AGVs and number of pallets in the system are varied. Other parameters like speed of AGVs, sequencing rule and dispatching rules are kept constant. Three, five and seven number of AGVs are used. Speed of AGVs are kept constant as 4 m/s. Number of pallets in the system is taken as eight, sixteen and twenty four pallets respectively. Responses of these input parameters are studied on make span time (MST) and machine utilization. MST is the time between first operation of first part and last operation of last part. Machine utilization is a ratio of total time machine was operating to the total time machine was available. First come first serve (FCFS) is taken as sequencing rule and minimum parts in the queue (MINQ) is taken as dispatching rule. Models are run for 9600 parts i.e. 1200 of each part type. Effect of number of AGVs on MST and machine utilization, for both the system configurations at three levels of number of pallets and two levels of routing flexibility is discussed in this paper.

5.1 Effects of Number of AGVs, Number of Pallets and Routing Flexibility on MST

Simulation models are run for both the system configurations. Number of pallets in the system is increased in every step. Effects of input variables are studied with respect of MST. MST is the time between first operation of first part and last operation of last part. Figure 5 shows the effect of number of AGV on make span time for In-out buffer model and Figure 6 shows for central buffer system when eight pallets are introduced in the system. It is observed that for eight pallets in the system, there is a little decrese in MST of input and output buffer system when AGV is incresed from three to five. On further increase of AGV in this system, there is no significant decrease in MST. Same pattern of MST is observed when routing flexibility is used in this system. On the other hand, there is significant decrease in MST of central buffer model when AGV is increased from three to five.

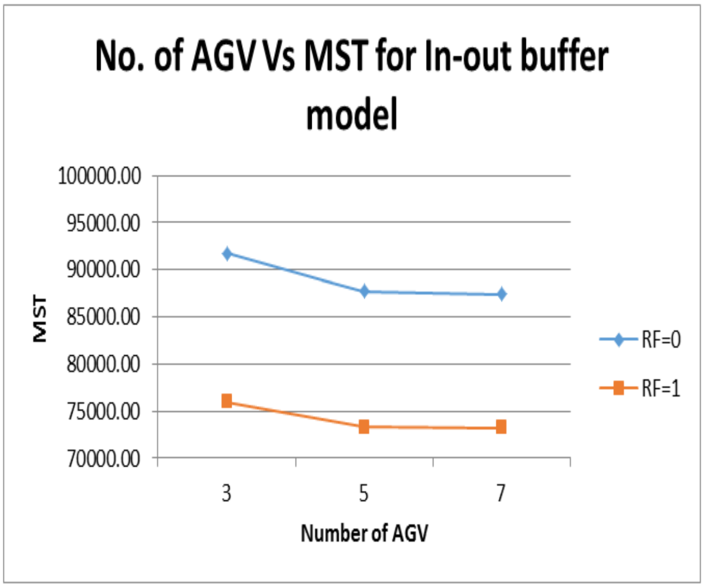

Figure 5 Effect of Number of AGVs on MST for 8 pallets (Input and output buffer)

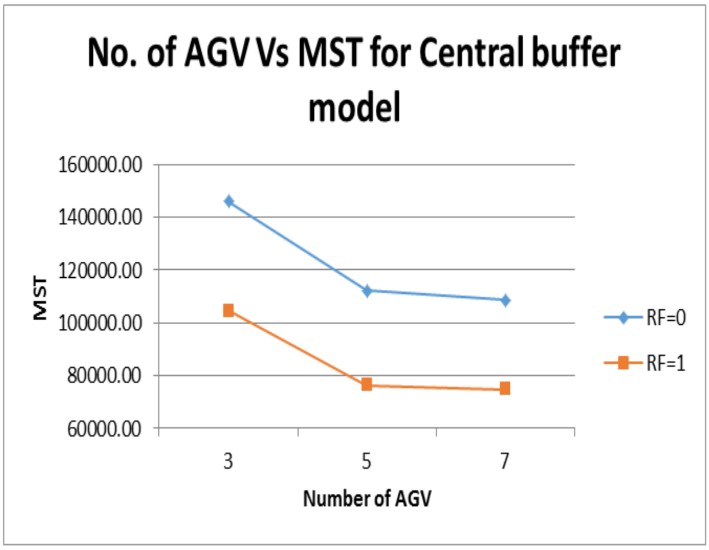

Figure 6 Effect of Number of AGVs on MST for 8 pallets (Central buffer)

It is seen from table 1 that there is 30% decrease in MST when AGV is increased from three to five. However on further increasing AGV, no significant improvement is observed in MST.

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

Similar pattern is observed when routing flexibility is used in this system. However at RF-1 percentage decrease in MST is more than that for RF-0 when we increase AGV from three to five.

Table 1: Percentage reduction in MST with increase in AGVsfor 8 pallets

In-out buffer model						Central buffer model				
AGV	**MST RF=0**	**% Reduction**	**MST RF=1**	**% Reduction**		**AGV**	**MST RF=0**	**% Reduction**	**MST RF=1**	**% Reduction**
3	91780.84		75980.88			3	145984.32		104401.80	
5	87736.50	4.6096	73315.86	3.63		5	112229.98	30.08	76417.02	36.62
7	87382.64	0.4050	73235.53	0.11		7	108751.34	3.20	74736.55	2.25

Figure 7 and figure 8 shows the pattern of MST with increase in number of AGV when 16 pallets are enterd in the system. It is observed that when AGV is increased from three to five there is significant decrease in MST of In-out buffer system. However further increase of AGV is not giving any significant decrease in MST. When routing flexibility in In-out buffer system is implemented, percentage improvement in MST with increase in AGVs is very less as compared to the condition when there is no routing flexibility. On the other hand there is significant decrease in MST of Central buffer model at each level increase in number of AGVs. From Table 2 it can be seen that when routing flexibility in Central buffer system is used, percentage decrease in MST is a little better than the condition when there is no routing flexibility.

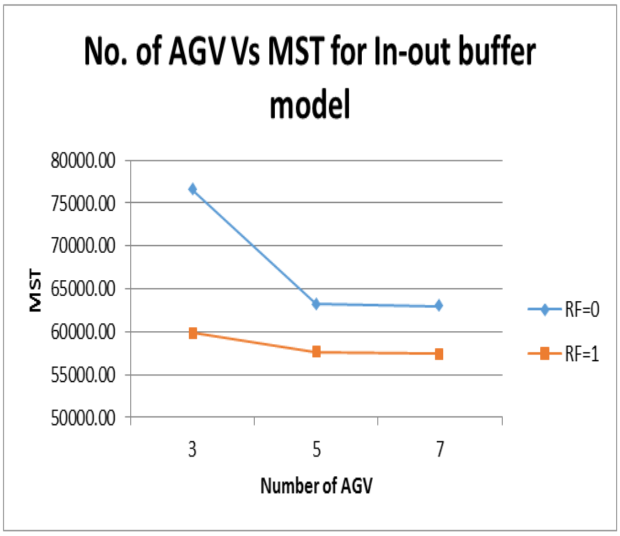

Figure 7 Effect of Number of AGVs on MST for 16 pallets(Input and output buffer)

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

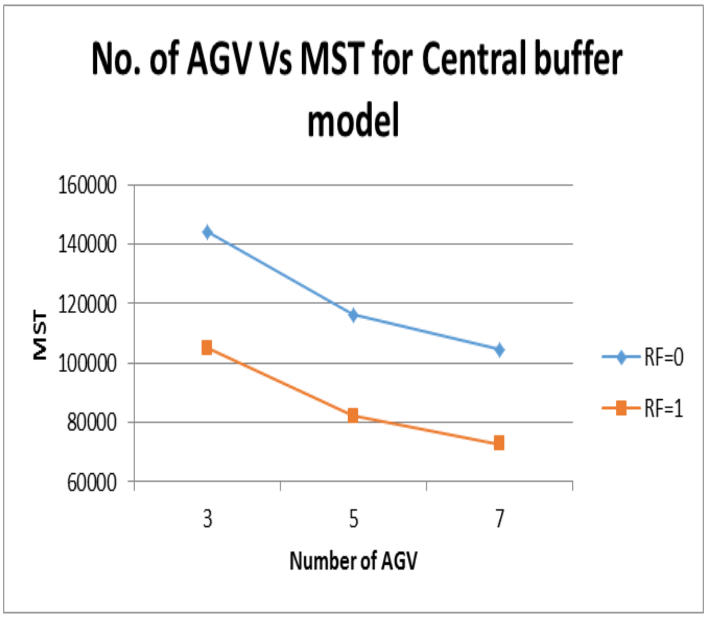

Figure 8 Effect of Number of AGVs on MST for 16 pallets (Central buffer)

Table 2: Percentage reduction in MST with increase in AGVsfor 16 pallets

In-out buffer model						Central buffer model				
AGV	**MST RF=0**	**% Reduction**	**MST RF=1**	**% Reduction**		**AGV**	**MST RF=0**	**% Reduction**	**MST RF=1**	**% Reduction**
3	76448.31		59937.62			3	144180.87		105009.78	
5	63203.69	20.96	57537.70	4.17		5	116352.55	23.92	82125.15	27.87
7	62928.20	0.44	57459.12	0.14		7	104543.27	11.30	72850.99	12.73

Figure 9 and figure 10 shows the effect of increase in AGVs on MST when 24 pallets are introduced in both system configurations. For Input and output buffer system increasing AGVs from three to five is resulting in about 30% decrease in MST as shown in table 3, but further increase in AGVs is not fruitful. Moreover increase in number of AGVs is not very much benificial when routing flexibility is used. On the other hand there is significant decrease in MST at each level increase in number of AGVs for central buffer system. Implementing routing flexibility is also very much fruitful for this sytem configuration.

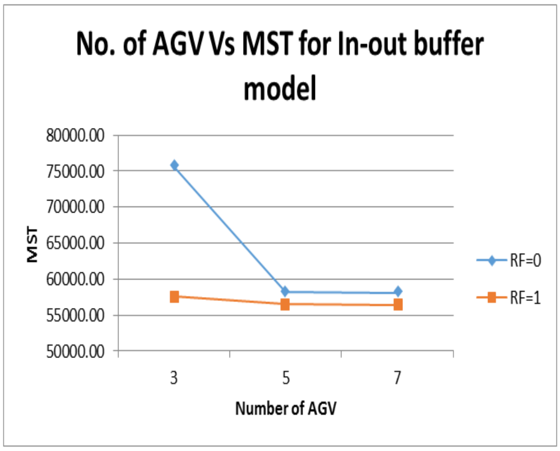

Figure 9 Effect of Number of AGVs on MST for 24 pallets (Input and Output buffer)

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

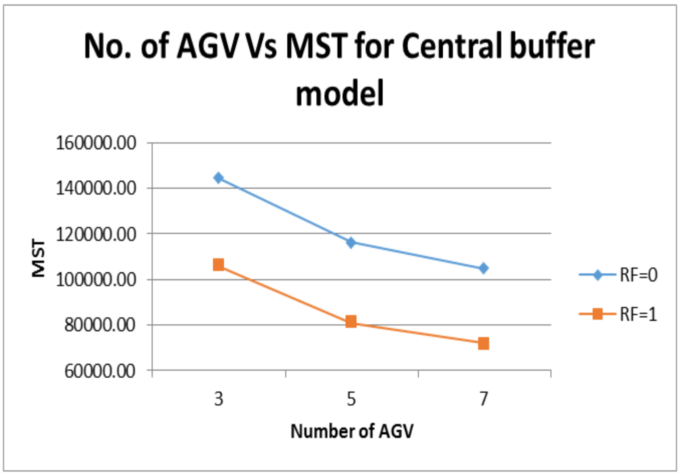

Figure 10 Effect of Number of AGVs on MST for 24 pallets (Central buffer)

Table 3: Percentage reduction in MST with increase in AGVsfor 24 pallets

In-out buffer model						Central buffer model				
AGV	**MST RF=0**	**% Reduction**	**MST RF=1**	**% Reduction**		**AGV**	**MST RF=0**	**% Reduction**	**MST RF=1**	**% Reduction**
3	75648.09		57649.05			3	145452.36		105422.38	
5	58214.12	29.95	56472.14	2.08		5	117183.06	24.12	80913.79	30.29
7	58137.27	0.13	56333.82	0.25		7	104304.62	12.35	71896.34	12.54

5.2 Effects of Number of AGVs, Number of Pallets and Routing Flexibility on Machine Utilization

Simulation models are run for both the system configurations. Number of pallets in the system is increased in every step. Effects of input variables are studied with respect of machine utilization. Machine utilization is a ratio of total time machine was operating to the total time machine was available. Figure 11 and figure 12 shows the effect of increase in number of AGVs on machine utilization for both the system configurations when number of pallets in the system is eight. It is observed that for input and output buffer system, increasing AGVs from three to five is resulting in very little increase in machine utilization. On further increasing number of AGVs, there is no increase in machine utilization. Introducing routing flexibility in input and output buffer system there is increase in machine utilization as compared to the condition when there is no routing flexibility.

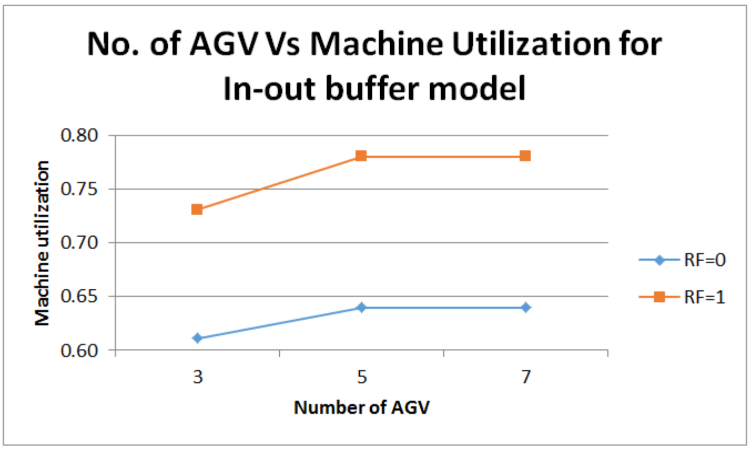

Figure 11 Effect of Number of AGVs on Machine Utilization for 8 pallets (Input and Output buffer)

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

As shown in table 4, for a particular routing flexibility in In-out buffer system, effect of increase in AGVs on machine utilization is very less. In the central buffer system configuration, increasing AGVs from three to five is resulting in significant increase in machine utilization at both level of routing flexibility. However in this system configuration further increase in AGVs is not beneficial. It is also observed that routing flexibility is further improving the performance of central buffer system. For nput and output buffer system at no routing flexibility there is about 17% increase in machine utilization on increase of AGVs from three to five as shown by graph in figure 9. Further increase in AGVs is not beneficial. For this system with fouting flexibility, increase in machine utilization is very less at first level increase of AGVs. Here also further addition of AGVs is not fruitful.

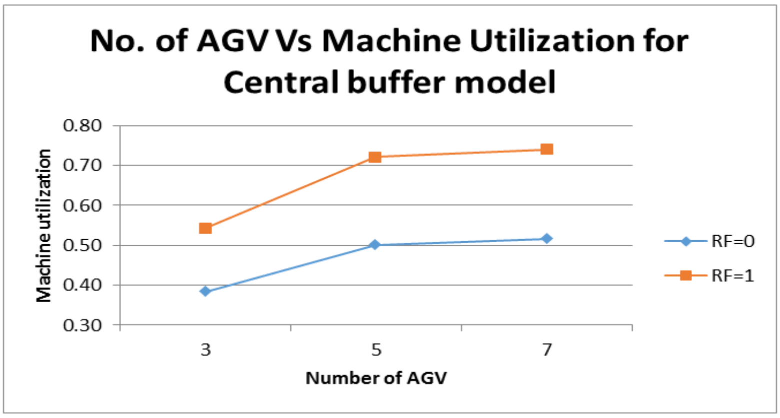

Figure 12 Effect of Number of AGVs on Machine Utilization for 8 pallets (Central buffer)

Table 4 Percentage increase in Machine Utilization with increase in AGVsfor 8 pallets

In-out buffer model						Central buffer model				
AGV	**M/C Utilization, RF=0**	**% Increase**	**M/C Utilization, RF=1**	**% Increase**		**AGV**	**M/C Utilization, RF=0**	**% Increase**	**M/C Utilization, RF=1**	**% Increase**
3	0.61		0.73			3	0.38		0.54	
5	0.64	4.50	0.78	6.32		5	0.50	23.12	0.72	24.64
7	0.64	0	0.78	0		7	0.52	3.10	0.74	2.51

Figure 13 and figure 14 shows the effect of number of AGVs on machine utilization for 16 pallets for both the system configurations. For the Central buffer system it is observed that there is significant increase in machine utilization at every level increase in AGVs for both level of routing flexibility. Table 5 suggest that increase in AGVs combined with routing flexibility level-1 gives maximum machine utilization.

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

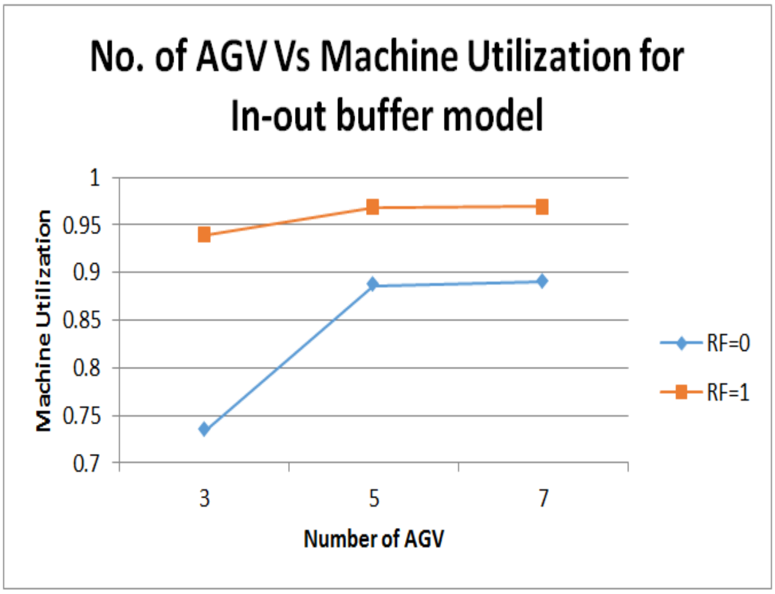

Figure 13 Effect of Number of AGVs on Machine Utilization for 16 pallets (Input and Output buffer)

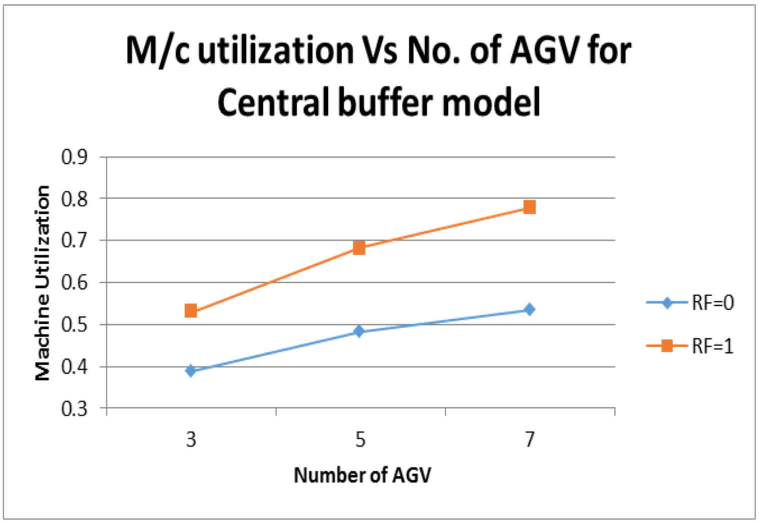

Figure 14 Effect of Number of AGVs on Machine Utilization for 16 pallets (Central buffer)

Table 5: Percentage increase in Machine Utilization with increase in AGVsfor 16 pallets

In-out buffer model						Central buffer model				
AGV	M/C Utilization, RF=0	% Increase	M/C Utilization, RF=1	% Increase		AGV	M/C Utilization, RF=0	% Increase	M/C Utilization, RF=1	% Increase
3	0.73		0.94			3	0.39		0.53	
5	0.89	17.33	0.97	3.52		5	0.48	19.29	0.68	22.51
7	0.89	0.44	0.98	0.46		7	0.54	10.15	0.78	12.12

Effect of number of AGVs on machine utilization for 24 pallets can be observed from figure 16 and figure 17 for both system configurations. For input and output buffer system, percentage increase in machine utilization is highest for 24 pallets as compared to 8 and 16

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

pallets when AGVsare increased from three to five. Here too further increase in AGVs is not increasing machine utilization significantly. Central buffer system show increase in machine utilization at each level increase in AGVs. From table 6 it is clear that adding more AGVs along with using routing flexibility gives maximum machine utilization.

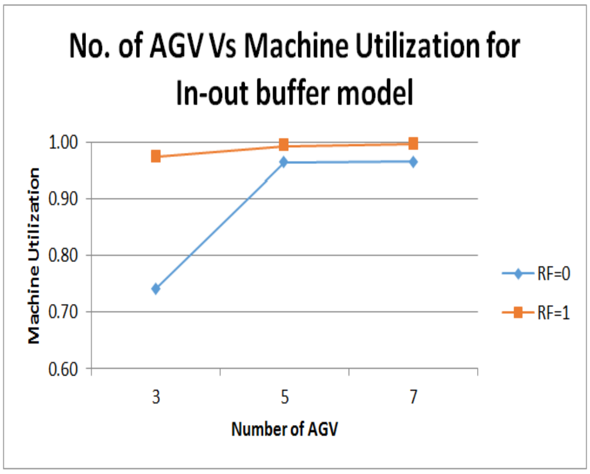

Figure 15 Effect of Number of AGVs on Machine Utilization for 24 pallets (Input and Output buffer)

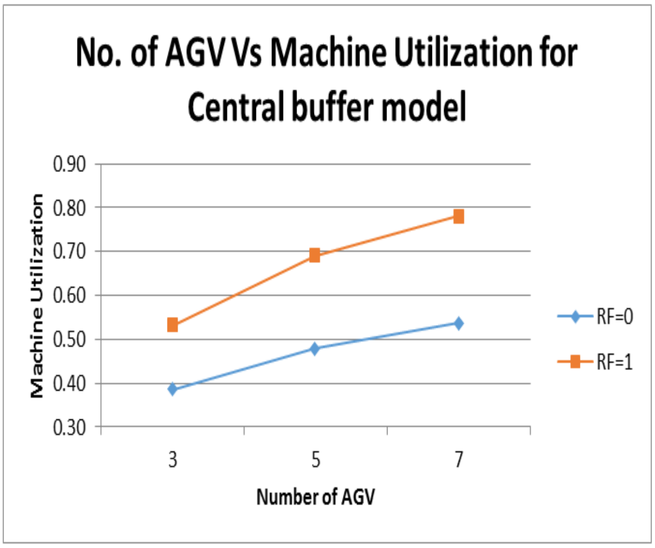

Figure 16 Effect of Number of AGVs on Machine Utilization for 24 pallets (Central buffer)

Table 6 Percentage increase in Machine Utilization with increase in AGVsfor 24 pallets

In-out buffer model						Central buffer model				
AGV	M/C Utilization, RF=0	% Increase	M/C Utilization, RF=1	% Increase		AGV	M/C Utilization, RF=0	% Increase	M/C Utilization, RF=1	% Increase
3	0.74		0.97			3	0.39		0.53	
5	0.96	23.05	0.99	1.96		5	0.48	19.45	0.69	23.18
7	0.97	0.12	1.00	0.34		7	0.54	10.99	0.78	11.51

6. CONCLUSION

Effect of AGV fleet size, buffer location, number of pallets in the system and routing flexibility is observed on performance measures namely MST and machine utilization. It is

ISSN-2394-5125 VOL 6, ISSUE 7, 2019

observed that for dedicated buffers at each machine system, adding more AGV is not useful when parts in the system are less. Moreover if parts in the system are increasing then number of AGV up to five is serving the purpose. It is also observed that for this type of system when parts in the system are increasing, there can be a choice between increasing AGV and implementing routing flexibility. Choosing only one of these two will give the similar system performance. Using both of them will cause additional cost to the system which can be avoided. For central buffer system, increasing AGV up to five is beneficial when parts in the system are less. Adding more than five AGV for lesser number of parts is not suggested. If number of parts in the system is increasing then adding AGV up to seven is improving the system performance. System performance is further improved if routing flexibility is also used along with increasing AGV. Analysis done in this paper will help system management deciding how and when manufacturing strategy can be changed for the benefit of organization.

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