北京

International Conference
on Industrial Engineering and Systems Management

IESM 2007

May 30 - June 2, 2007

BEIJING - CHINA

二〇〇七

Real-Time Selection of Process Plan in Flexible Manufacturing Systems: Simulation Study [*]

Ahmed HASSAM [a], Zaki SARI [b]

[a] Laboratory of Automatic of Tlemcen, University of Aboubekr Belkaïd, PoBox 230, Tlemcen 13000, Algeria.

[b] Laboratory of Automatic of Tlemcen, University of Aboubekr Belkaïd, PoBox 230, Tlemcen 13000, Algeria.

Abstract

This paper presents the results of a simulation study of a typical flexible manufacturing system (FMS) that has routing flexibility. The objective in this study is to test the effectiveness of the modified dissimilarity maximization method (modified DMM) for real time FMS scheduling. modified DMM method is an improvement of the DMM method. Modified DMM method is an alternative process plan selection method developed for routing selection in real time FMS scheduling. A computer simulation model, which mimics a physical system, is used to evaluate the effect of DMM and Modified DMM rules on the system performance. The typical FMS employed in this study includes seven machining centres, a loading and unloading area, and six different part types. The part type has alternative routings because of the existence of identical machining centre in the system. The DMM and Modified DMM are used for selecting an incoming part and later routing it to a machining centre for its next operation. The result show that the Modified DMM outperforms DMM on system throughput in saturation case, increases utilization of the machines and increases utilization of the handling system.

Key words: Flexible Manufacturing Systems, Routing, Real-time FMS control, Dispatching rules, Simulation

---

1 Introduction

To achieve rapid response to customer demands, flexibility has become a key concept in the design and control of manufacturing systems. Flexible manufacturing systems were developed to combine the flexibility of conventional job shops and the productivity of flow lines. FMS consist of a computer controlled and an integrated configuration of numerically controlled machine tools inter-linked with automated material handling systems FMSs have been defined in a number of ways. Most of the definitions are based on the hardware used in the system. Other definitions are based on the capability or performance of the system. In a FMS each machine is quite versatile and capable of performing many different operations, therefore each part may have alternative routings in the system. The complexity due to the random part arrivals makes the real time routing selection and control problems multidimensional in nature.

In this paper we present Modified DMM as an alternative process plan selection method developed for real-time alternative routings selection in Flexible manufacturing systems.

---

[*] This paper was not presented at any other revue. Corresponding author A. Hassam. Tel +21343285689. Fax +21343285685.

Email addresses: a_hassam@mail.univ-tlemcen.dz (Ahmed Hassam), z_sari@mail.univ-tlemcen.dz (Zaki Sari).

This paper employs a simulation model to evaluate the effects of Modified DMM and DMM rules on the performance of a flexible manufacturing system that consists of seven machining centres, a loading and an unloading area, and six different part types. The simulation model mimics a real FMS. Each part type has alternative routings owing to the alternative machining centres in the system.

This paper is organized as follows: The related literature is given in section 2. The FMS model used in this study is described in section3. In section 4 we explained the DMM and Modified DMM rules. Simulation results are given in section 5. Finally, we present the conclusions and recommendations for future work in section 6.

2 Literature Review

In general, scheduling involves decisions of allocating resources to tasks over time, and optimizing one or more objectives. Scheduling models can be either deterministic or stochastic. Deterministic models assume that all job data are known exactly in advance. In stochastic models, not all job data but their distributions are known. Static scheduling problems assume that a list of n jobs are available at the beginning of the scheduling period, while the dynamic scheduling problems deal with an ongoing situation, in which new jobs are continuously added to the system. The general scheduling problem is a NP-hard type of problem [1].One of the earliest studies on the FMS scheduling problem in the work of Nof et al. [2] who demonstrated the importance of scheduling decisions for system performance. From a traditional viewpoint, scheduling is an off-line activity where operations that are known prior to production are scheduled before the production starts. The potential problem with the off-line scheduling is rescheduling, because any off-line schedule is almost immediately subject to inevitable changes. Therefore the traditional off-line scheduling approaches cause increased waiting times, increased work-in-process, low equipment utilisation, and eventually degrade the system performance. [3],[4].Several researchers propose various methods to accommodate flexibility into off-line scheduling in order to increase the system performance [5], [6]. However, real time scheduling has always remained e desirable but elusive goal [7], [8]. real time scheduling and control FMS have been popular research areas since the beginning of the 1980swhen flexible manufacturing systems started gaining acceptance by the industrialised countries [9].

Owing to the lack of successful analytical methods, simulation has been used for real-time scheduling of FMS by several researchers. The framework of simulation based real-time FMS scheduling includes a simulation model linked to a physical system. Many studies in real-time FMS scheduling and control area do not consider the influence of routing flexibility [10]. Most of the studies that consider routing flexibility in FMS focus on the problem of routing selection prior to production [11]. This approach is not applicable to random type FMS. The control system of a random type FMS is required to have the capability to adapt to the randomness in arrivals and other unexpected events in the system by effectively using operation and routing flexibility in real-time. The lack of real-time FMS scheduling methods that effectively use operation and routing flexibility is the driving force behind this paper. The objective of this study is to test the effectiveness of Modified DMM method for real time FMS scheduling, and compare this method with the DMM method.

3 FMS Model

The hypothetical FMS is assumed to be composed of :

1. Two vertical milling machines (VMC).
2. Two horizontal milling machines (HMC).
3. Two vertical turning centres (VTC).
4. One shaper (SHP).
5. One loading station (L).
6. One unloading station (UL).

This FMS configuration is shown in Figure 1[12].

Each machine in the system has an input and output buffer and there are six part types.

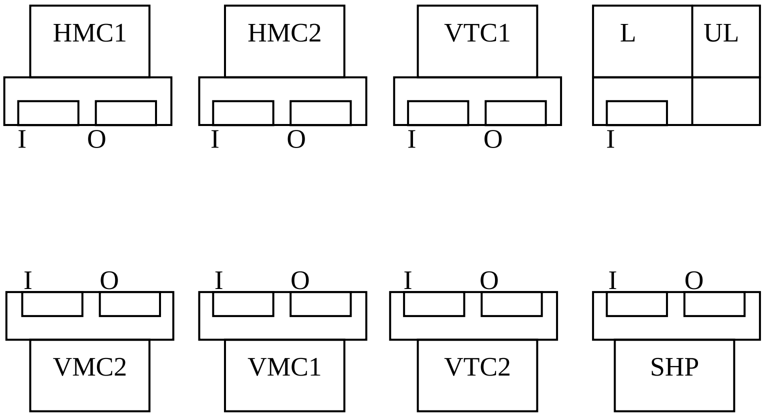
The alternative routes and processing times of each part type and the production ratio of the part types that are randomly arriving at the loading station are shown in Table 1.

The operation of the FMS model used in this study is based on the following assumptions:

1. The flexible process plan (i.e. alternative routings) of each part type is known prior to production.
2. Processing times are known deterministically and they include tool change, set-up, and machining times.
3. The processing time of an operation is the same on the alternative machines identified for that operation.
4. Each machine can process only one part at a time.

Part type	Production ratio	Routings and Processing time (min)
A	17%	L – VTC1 (30) – VMC1 (20) - UL
		L – VTC1 (30) – VMC2 (20) – UL
		L – VTC2 (30) – VMC1 (20) – UL
		L – VTC2 (30) – VMC2 (20) - UL
B	17%	L – VTC1 (20) – SHP (1) – VMC1 (15) – UL
		L – VTC1 (20) – SHP (1) – VMC2 (15) – UL
		L – VTC2 (20) – SHP (1) – VMC1 (15) – UL
		L – VTC2 (20) – SHP (1) – VMC2 (15) – UL
C	17%	L – VTC1 (40) – VMC1 (25) - UL
		L – VTC1 (40) – VMC2 (25) – UL
		L – VTC2 (40) – VMC1 (25) – UL
		L – VTC2 (40) – VMC2 (25) – UL
D	21%	L – VTC1 (40) – SHP (1) – VTC1 (20) – HMC1 (35) – UL
		L – VTC1 (40) – SHP (1) – VTC1 (20) – HMC2 (35) – UL
		L – VTC1 (40) – SHP (1) – VTC2 (20) – HMC1 (35) – UL
		L – VTC1 (40) – SHP (1) – VTC2 (20) – HMC2 (35) - UL
		L – VTC2 (40) – SHP (1) – VTC1 (20) – HMC1 (35) - UL
		L – VTC2 (40) – SHP (1) – VTC1 (20) – HMC2 (35) - UL
		L – VTC2 (40) – SHP (1) – VTC2 (20) – HMC1 (35) - UL
		L – VTC2 (40) – SHP (1) – VTC2 (20) – HMC2 (35) - UL
E	20%	L – VTC1 (25) – SHP (1) – VTC1 (35) – HMC1 (50) - UL
		L – VTC1 (25) – SHP (1) – VTC1 (35) – HMC2 (50) - UL
		L – VTC1 (25) – SHP (1) – VTC2 (35) – HMC1 (50) - UL
		L – VTC1 (25) – SHP (1) – VTC2 (35) – HMC2 (50) - UL
		L – VTC2 (25) – SHP (1) – VTC1 (35) – HMC1 (50) - UL
		L – VTC2 (25) – SHP (1) – VTC1 (35) – HMC2 (50) - UL
		L – VTC2 (25) – SHP (1) – VTC2 (35) – HMC1 (50) - UL
		L – VTC2 (25) – SHP (1) – VTC2 (35) – HMC2 (50) - UL
F	8%	L – HMC1 (40) – UL
		L – HMC2 (40) – UL

Table 1. Alternative routings of part types [12].



HMC: Horizontal Machining centre.
VMC: Vertical Machining centre.
VTC: Vertical Turning centre.
SHP: Shaper.
L: Loading Station.
UL: Unloading Station.
I : Input Buffer.
O : Output Buffer.

Fig. 1. Configuration of the FMS model [12].

4 Operational Control DMM and Modified DMM Rules

As shown in figure 1, the FMS considered for this study includes seven machining centres, a loading and an unloading station, and six different part types, each part types have alternative routings (see Table 1). Two simulation models with two operational control rules, namely Dissimilarity maximisation method / first-in first-out (DMM/FIFO) and Dissimilarity maximisation method modified/ first-in first-out (Modified DMM /FIFO) are used for selecting an incoming part and later routing it to a machining centre for its next operation. DMM and Modified DMM are an alternative process plan selection method in developed for routing selection in real-time of FMS.

4.1 Presentation of DMM rule:

DMM [12] is developed with the goal of reducing the congestion in the system, The DMM concept is based on the objective of maximising the dissimilarities among the alternative routings. DMM uses a dissimilarity coefficient, wich is based on the types of machines in routings. It selects a routing for each part so that the cumulative dissimilarity, in terms of machine tool requirements, is maximised. Dissimilarity between routings I and j is defined as follows:

$$D_{ij} = \frac{\textit{Number of machine types that are not common in both routings } i \textit{ and } j}{\textit{Total number of machine types in both routings}} \qquad (1)$$

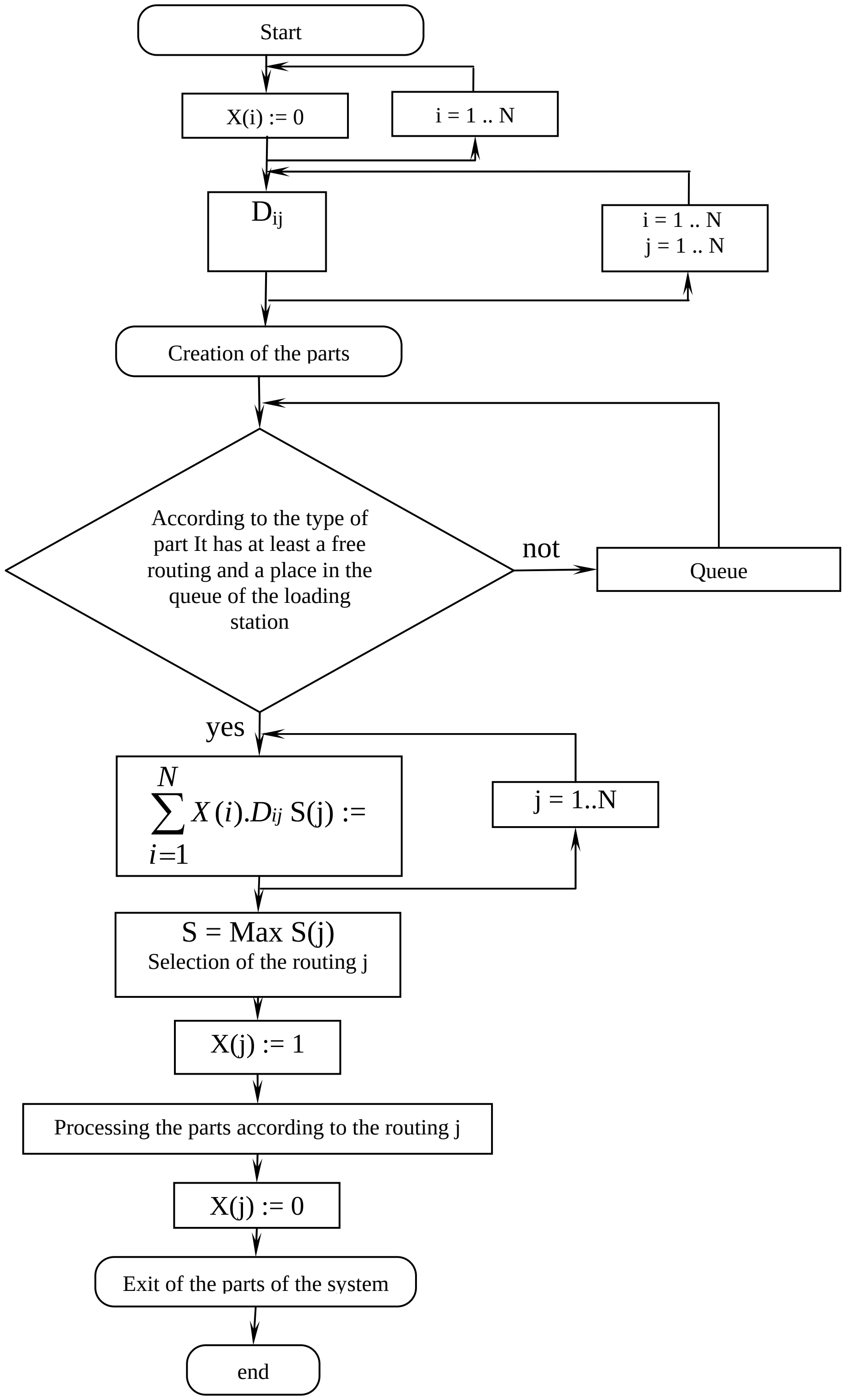
The following flow chart (see figure 2) explains the algorithm of the DMM method.

4.2 Presentation of Modified DMM rule [13]:

In this section we will explain the modified DMM rule which we developed starting from DMM rule already quoted previously, this rule is also used in the selection of the alternative routings in real time in a FMS. In our study of DMM rule, we noticed that for an important rate of creation of parts and for a small size of queues :

1. The system of production is saturated.
2. The utilisation ratio of the machines and the AGV is rather weak.

What will influence on the performances of the system of production. For that we proposed modified DMM rule in the goal to improve DMM rule and to increase the performances of the system of production, thus increase the production rate and increase the use of the machines and the system of transport. In DMM rule, after having selected a routing for a part, this routing cannot be used by another part as long as the first part did not leave the system thus each routing can contain only one part at the same time. Our modification of this rule, aim at keeping the same principle which depends on the maximization of the coefficients of dissimilitude for the selection of the various alternative routings, but by assigning several parts to only one routing. Then if all routings are selected by a part, the following part will be transfer in the routing where the queue of the first machine of this routing, contains at least a free place. The Modified DMM is explained in the figure 3.



X(i), X(j) : The state of routing i ;

$$X(i) = \begin{cases} 0 \; \textit{if the routing } i \textit{ is not selected.} \\ 1 \; \textit{otherwise.} \end{cases}$$

D_{ij} : the coefficient of dissimilitude between routings i and j

Fig.2. Flow chart of DMM rule [13].

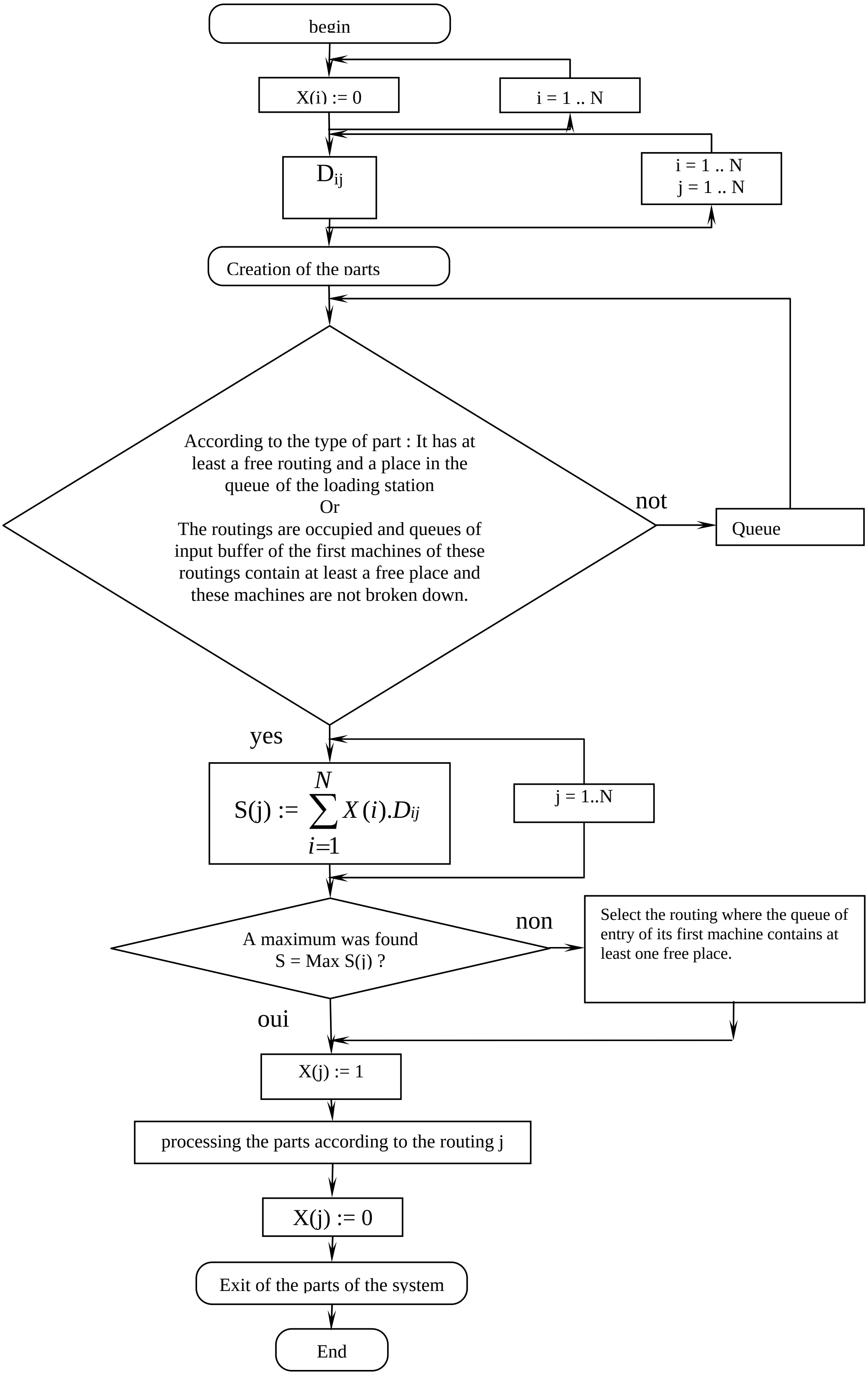


Fig.3. Flow chart of Modified DMM rule [13].

5 Simulation Result

In order to show the improvements made by modified DMM method [Saygin et Kilic 99] we made several studies in simulation with variations on the criteria of the studied system. The following results are obtained after the simulation of the FMS model by ARENA software.

5.1 Production rate

In this paragraph we present the results on the production rate. These results are the average of ten replications, obtained after the simulation of the two methods. Rate of part leaving the system is calculated by dividing the number of parts left the system on the number of parts created, in order to make a standardization.
The figure 4 shows that for a significant rate of creation of the parts results obtained by modified DMM method are better than those of the DMM and that below the rate creation 1/25 the production rate is practically the same one for the two methods.

Rate of creation of the parts (1/min)		1/40	1/35	1/30	1/25	1/20	1/15	1/10	1/5
Rate of part leaving the system (%)	**Modified DMM**	99,99	99,99	99,98	99,71	84,47	60,73	41,67	21,15
	DMM	99,99	99,99	99,97	81,4	24,65	32,05	15,43	8,88

Table.2. Rate of part leaving the system for queue size=2.

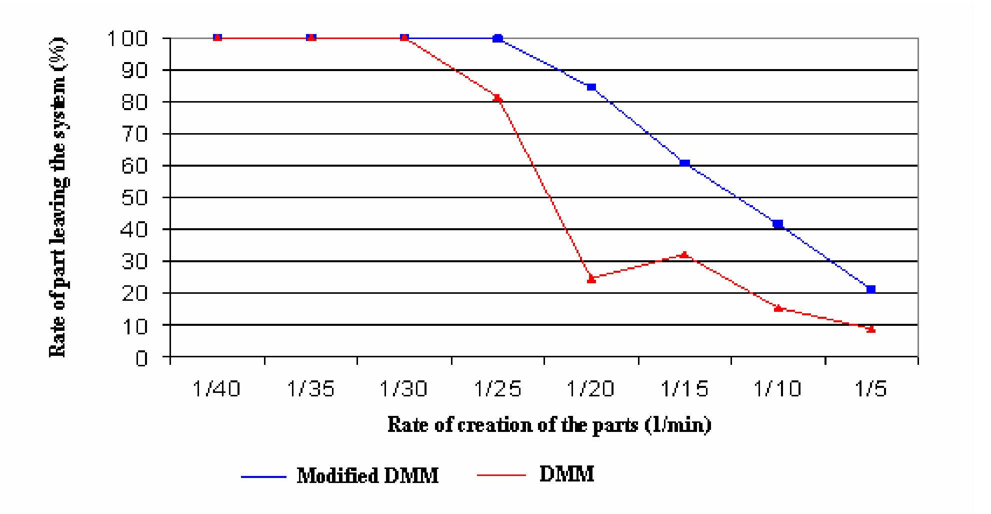


Fig.4. Rate of part leaving the system for queue size=2.

5.2 Utilisation rate of the machines:

The utilisation rate of the machines is a very significant criterion in the measurement of the performance of a system of production. The utilisation rate for the machines VTC 1 and VTC2 is more significant for the DMM modified than for the DMM for a significant rate of creation (higher than 1/25) (see figure 5).

Rate of creation of the parts (1/min)		1/40	1/35	1/30	1/25	1/20	1/15	1/10	1/5
Utilisation rate of the machines VTC1 and VTC2 (%)	**Modified DMM**	49,97	56,94	66,59	79,85	84,52	82,72	83,58	84,70
	DMM	49,94	57,00	66,56	65,05	24,62	42,59	30,90	35,50

Table.3. Utilisation rate of the machines VTC1 and VTC2 for queue size=2.

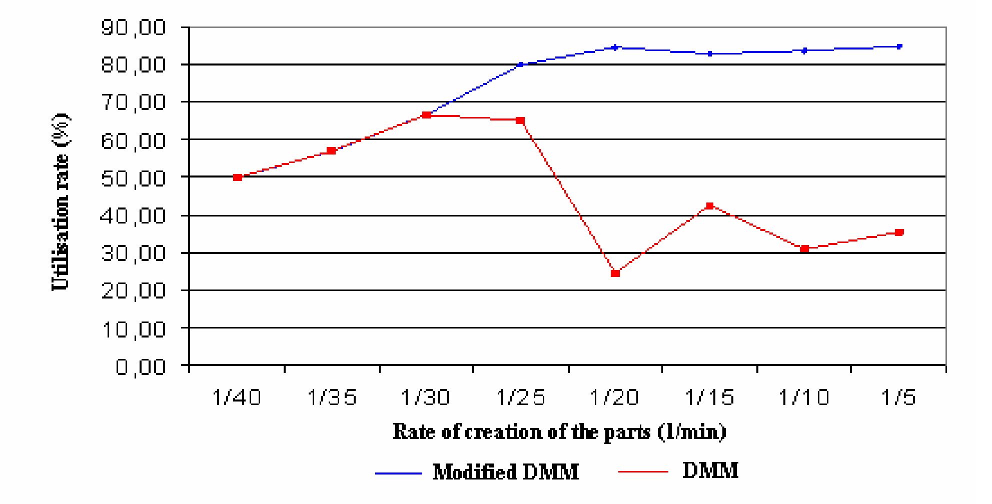


Fig.5. Utilisation rate of the machines VTC1 and VTC2 for queue size=2.

5.3 Utilisation rate of the handling system

Figure 6 shows us that for a system saturated the ratio utilisation of the AGV is more significant for modified DMM rule, which is due to the high production rate and the increase in the use of the machines.

Rate of creation of the parts (1/min)		1/40	1/35	1/30	1/25	1/20	1/15	1/10	1/5
Utilisation rate of the AGV (%)	**Modified DMM**	14,98	17,46	21	27,31	30,26	29,16	30,19	30,44
	DMM	15	17,4	20,93	21,67	8,43	14,35	10,55	12,08

Table.4. Utilisation rate of AGV for queue size=2.

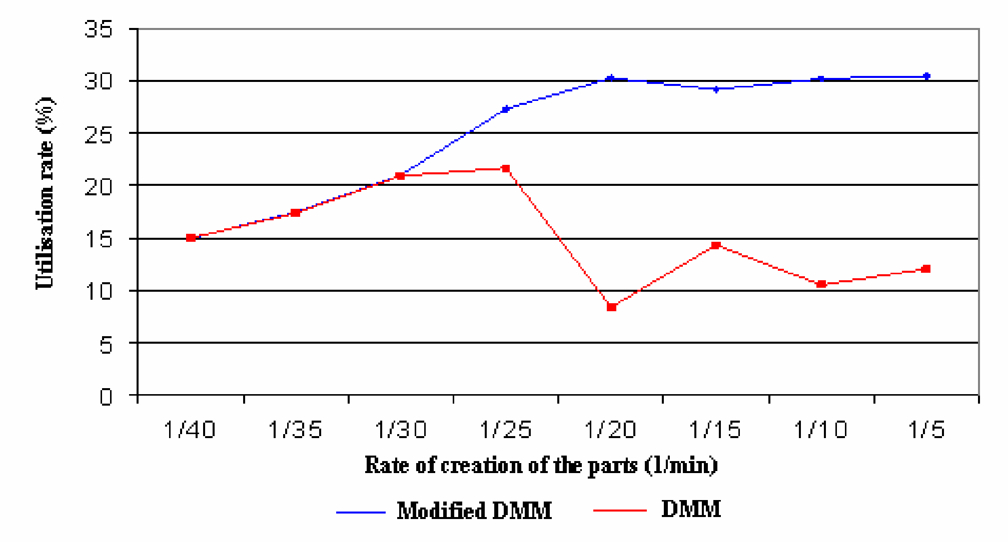


Fig.6. Utilisation rate of AGV for queue size=2.

6 Conclusion

The results obtained showed all that modified DMM method gave results better than method DMM for a saturated system of production. For high rates of creation of part modified DMM method clearly increased the performances of the system of production from where increase in the production rate, increase in the utilisation rate of the machines and increase in the use of the handling system. Because of the complexity of the FMS, this method could not improve the performances concerning the cycle time and the rate of the work-in-progress of the system. That is due to the fact that the number of parts which circulate in the system is higher during the use of modified DMM method.

We can conclude that the performance of the rules of priority or of selection of routing such as the modifée DMM depends on the configuration of the workshop and operating conditions. Thus we suggest for a selection of alternative routings in real time combining the modified rule DMM which we proposed with other rules of priority or to initially select the rules of priority according to the state of the real workshop.

7 References

[1] J. Liu, B. L. MacCarthy (1997). “A goal MILP model for FMS scheduling”, European journal of operational research, 100, 441-453.

[2] S. Nof, M. Barash, J. Solberg (1979). “Operational control of item flow in versatile manufacturing system”, International journal of production research, 17, 479-489.

[3] S. Y. D. Wu, R. A. Wysk (1989) “An application of discrete event simulation to on-line control and scheduling in flexible manufacturing”, International journal of Production Research, 27, 1603-1623.

[4] N. Ishii, M. Muraki (1996). “A process-variability-based on-line scheduling system in multi product batch process”, Computing in Chemical Engineering, 20, 217-234.

[5] C. Saygin, S.E. Kilic (1999). ”Integrating flexible manufacturing systems with scheduling in flexible manufacturing system”, International journal of advanced Manufacturing Technology, 15(4),268-280.

[6] C. Saygin, S. E. Kilick (1996). “Effect of flexible process plans on performance of flexible manufacturing systems”, proceedings of 7th International DAAM symposium, Vienna, Austria, 393-394.

[7] C. Basnet, J. H. Mize (1994). ”Scheduling and control of flexible manufacturing systems: a critical review ”, International journal of Computer Integrated Manufacturing, 7(6), 340-355.

[8] C. S. Shukla, F. F. Chen (1996). “The state of the art in intelligent real-time FMS control: a comprehensive survey”, Journal of intelligent Manufacturing, 7, 441-455.

[9] C. Peng, F.F. Chen (1998). "Real-time control and scheduling of flexible manufacturing systems : a simulation based ordinal optimization approach", International Journal of Advenced Manufacturing Technology, 14 (10), 775-786.

[10] A. Kazerooni, F. T. S. Chan, K. Abhary (1997). "A fuzzy integrated decision-making support system for scheduling of FMS using simulation", Computer Integrated Manufacturing Systems, 10 (1), 27-34.

[11] H. Cho, R. A. Wysk (1995). "Intelligent workstation controller for computer-integrated manufacturing : problems and models", Journal of Manufcturing Systems, 14(4), 252-263.

[13] C. Saygin, F.F. Chen, J. Singh (2001). “Real-Time Manipulation of alternative Routings in Flexible Manufacturing Systems: A simulation Study”, International journal of advanced Manufacturing Technology, 18, 755-763.

[14] A.Hassam (2006). “Manipulation des routages alternatifs en temps reel dans les systèmes flexibles de production”, Université Abou-bekr Belkaîd Tlemcen Algérie.