

# A Fuzzy-Multicriteria Based Approach for Job Sequencing and Routing In Flexible Manufacturing System (Fms)

Abdullah Al Mamun <sup>1</sup>

<sup>1</sup> Bangladesh University of Engineering and Technology

*Received: 8 December 2011 Accepted: 31 December 2011 Published: 15 January 2012*

---

## Abstract

Flexible manufacturing systems (FMS) are production systems consisting of identical multipurpose numerically controlled machines (workstations), automated material handling system, tools, loading and unloading stations, inspection stations, storage areas and a hierarchical control system. Job sequencing and routing are fundamental components of FMS. A flexible manufacturing system (FMS) is a manufacturing system in which there is some flexibility that allows the system to react in the case of changes. Scheduling of an FMS is very complicated, particularly in dynamic environment. A simulation based FMS scheduling system can take into account these uncertainties and perform accordingly. Fuzzy logic based simulation is easy to apply and can consider a number variables with reasonable amount of accuracy. Here the proposed model will prioritize the job and select the best alternative route with multi-criteria scheduling through an approach based on a fuzzy logic. There are three criteria for both the job sequencing and routing with 27 rules. With the help of the rules the sequence of the jobs are done and the best route is selected.

---

**Index terms**— Flexible Manufacturing System (FMS), Fuzzy Logic, Scheduling, Job Sequencing, Routing.

## 1 Introduction

he present industrial trend of manufacturing low cost low-to-medium volumes of modular products with high variability demands manufacturing systems with flexibility and low delivery times. This led to manufacturing systems with small batch productions, low setup times and many decisional degrees of freedom. Those systems are flexible manufacturing systems (FMS). They are highly automated systems with many redundancies, thus allowing for many degrees of freedom in the decision process. Even though there are no universally accepted definitions of FMSs, according to what is proposed by Tempelmeier and Kuhn (1993) and Viswanadham and Narahari(1992) an FMS is composed of:

? Numerically controlled (NC) multipurpose machine, with automated tool exchange.

? Automated materials and tools handling system (MHS), made by conveyor belts, automatic guided vehicles (AGV), industrial robots, etc.

? Load and unload stations that manage the loading and unloading of parts (loaded parts are fixed on pallets);

? Inspection stations (for quality control);

? Storage areas like input, output and input-output buffers for every machine, or centralized buffers;

? Tools storage areas;

? Hierarchical control system that manages the MHS, all the parts and tools movements and loading and unloading of parts in stations and machines.

A FMS has some built in "hardware" redundancies that should give it the necessary flexibility. These redundancies, although useful, create difficult control problems, i.e. the search for the "best" action to take in a particular situation. The real problem in achieving the desired flexibility presently consists of finding a

43 correct "solution" of the control problem. Such a problem is typically divided into three hierarchical problems  
44 characterized by the time frame they refer to long, medium and short-term control. This study will focus on  
45 the short term control, or scheduling, problem. The most appropriate control of an FMS requires real time  
46 control and state feedback. This way all the dynamic characteristics of the system are taken into account. This  
47 means that job schedules cannot be predetermined (i.e., predictive scheduling) but they need to be adapted to  
48 the current state and goals during the evolution of the system (i.e., reactive scheduling). Moreover, the best  
49 decisions can be taken by using all the available information on the state of the system.

50 In practice, human experts are the ones that, by using practical rules, make an FMS work to the desired  
51 objective. This leads to the idea of a scheduling approach that mimics the behavior of human experts, that is  
52 the emerging field of intelligent manufacturing. The literature offers a wide variety of intelligent techniques for  
53 the scheduling of manufacturing systems. Namely, fuzzy logic systems (FLS), artificial neural networks (ANN),  
54 genetic algorithms (GA), artificial intelligence (AI) and hybrid systems are used in scheduling. AI based systems  
55 (i.e., more precisely expert systems) are useful in scheduling because of their ease in using rules captured from  
56 human experts, even though presenting some limitations.

57 Fuzzy logic has the ability to simultaneously consider multiple criteria. Furthermore, the advantage of the  
58 fuzzy logic system approach is that it incorporates both numerical and linguistic variables. In this paper, we  
59 apply fuzzy logic to simulate FMS. The fuzzy based simulation, in this paper, is designed to solve the problem  
60 of determine the job sequence and selecting the best part route. The simulation via a fuzzy model is shown in  
61 figure ??.

62 Fig. ?? : Structure of a Fuzzy Logic System Fuzzy logic, which was introduced by Zadeh (1965), has been  
63 applied to various industrial problems. The advantage of the fuzzy logic system approach is that in incorporates  
64 both numerical results from previous solutions or simulation and the scheduling expertise from experience or  
65 observation or hypothetical data, and it is very easy to implement. Several Fuzzy logic based scheduling systems  
66 have recently been developed. Using fuzzy logic to control flexible manufacturing systems seems very appropriate  
67 due to its simplicity in dealing with uncertain data, along with the multi-objective nature of the problem. Hintz  
68 and Zimmermann(1989), are probably the first to propose a production planning and control system that uses  
69 fuzzy set theory. The interesting part of their work consists in the application of approximate reasoning techniques  
70 to both the sequencing and the priority setting problems. The authors develop a hierarchy of elements that are  
71 important to make a decision in both cases. Those elements become the antecedents of the fuzzy rules in the  
72 scheduling procedure. This methodology is quite general, thus it can be easily modified and extended by changing  
73 the antecedents. The consequent of the rules are the next job to be entered into the system (sequencing) or to be  
74 processed (priority setting). Angsana and Passino (1994) seem to be the first to have a more systematic approach  
75 to the problem. They present a fuzzy controller for the priority setting problem along with a procedure that  
76 can be used for both design and adaptation. Watanabe et. al (1997) proposed a fuzzy scheduling mechanism for  
77 job shops, that they name FUZZY. The only problem that they actually attack is the priority setting problem  
78 for a free machine choosing in its buffer the next job to serve. Grabot (1993) proposed a routing mechanism  
79 that embodies expert knowledge and that reacts to resource failures by using fuzzy logic and possibility theory.  
80 Angsana and Passino(1994) proposed a new scheduling technique which was designed to emulate human scheduler.  
81 The implemented Fuzzy Controller (FC). Sentieiro use fuzzy set theory in a non-classic approach called FLAS  
82 (fuzzy logic applied to scheduling) for short term planning and scheduling. learning from fuzzy rules and previous  
83 solutions. In this research work, Fuzzy logic is applied to generate a fuzzy scheduling model in order to select  
84 the best job sequence and part routing for the jobs II.

## 2 Fuzzy logic in Job Sequencing and Routing

86 The present industrial trend of manufacturing low cost low-to-medium volumes of modular products with high  
87 variability demands manufacturing systems with flexibility and low delivery times. This led to manufacturing  
88 systems with small batch productions, low setup times and many decisional degrees of freedom. The scheduling  
89 problem consists of several decisional points. A first division into four parts can be made:

- 90 ? Timing: that is, when to insert a part into the system;
- 91 ? Sequencing: that is, defining the order with which different parts (batches, orders) are inserted into the  
92 system;
- 93 ? Routing: that is, defining the route (machine, AGV, etc.) for a part in presence of alternatives;
- 94 ? Priority setting: that is, defining a priority for parts, machine and resources in general so that a choice is  
95 directly implied.

96 The Fuzzy scheduler considers two particular rules in the scheduling problem: Sequencing of job and routing.  
97 The sequencing of jobs was approached using fuzzy controllers having rules with three antecedents (Processing  
98 time, Due date and Profit over Cost) and one consequent (Priority). The FLSs determine the priority of each job  
99 waiting for loading or in a machine buffer, so that whenever the load station or the machine are free the job with  
100 the highest priority among those waiting is chosen. The last decisional point that was considered is the routing  
101 problem, that is, the choice of one among many possible routes. In the problem considered this is equivalent to  
102 choosing the machine for next processing of a job, among the possible alternatives for that job.

103 The following assumptions on the FMS were made:

- 104 1. Tool management is not considered, i.e. it is supposed that all the tools are available where needed. 2.

---

105 Failure of workstations and/or transport systems is not considered, i.e., the machines and/or transport subsystem  
106 are not subject to failure.

### 107 **3 Orders arrive to the FMS as Poisson processes**

108 with a fixed inter-arrival time. 4. Production of orders occurs in batches, and the movement of the whole batch  
109 is considered, so that batch dimensions are not important.

110 5. Setup times are independent of the order in which operations are executed, i.e. they are constant and  
111 embodied in the operation times of each job (batch). 6. There are as many pallets and fixtures as are needed  
112 (this assumption is mitigated by the fact that the number of jobs in the system is constantly controlled). 7. The  
113 routing of every job is random and directly defined as a sequence of workstations the job has to go through.  
114 Thus, the route of a job is not defined in terms of the operations needed by the job. In other words, every  
115 operation corresponds directly to the workstation that will execute it, i.e., the routing is defined as a sequence  
116 of workstations (i.e., workstation 1, 5, 6, 2). 8. There can be multiple routing choices, i.e. at a certain point a  
117 job can be equivalently sent to different workstations (as specified in its routing plan) having different processing  
118 times. 9. Loading, unloading and processing times are random. 10. Due dates are assigned according to the total  
119 processing time of a job. 11. Each workstation can work only one job at a time. 12. The transport system is  
120 composed of automated guided vehicles (AGVs) and each AGV can transport only one job at a time. 13. Neither  
121 the weight of a piece nor the dimension of a batch affects the speed of AGVs, which is assumed to be constant.  
122 14. Every workstation has one input buffer and no output buffer, therefore it will be free as soon as there is  
123 one free AGV that can transport the processed job to another workstation. 15. Delays in accessing the state  
124 information are neglected. 16. Among all the possible scheduling rules (Fanti contains a list of rules for a quite  
125 general FMS), the following are considered: ? Sequencing for a job (selection of a piece among those waiting to  
126 receive service from a machine); ? Routing decisions concerning the next required workstation.

127 III.

### 128 **4 Problem Definition**

129 The FMS described in this paper consists of 4 different CNC machining centers with finite local buffer capacity,  
130 all capable of performing the required operations on each part type, a load/unload station and material handling  
131 system with an automated guided

### 132 **5 Global Journal of Researches in Engineering**

### 133 **6 35**

### 134 **7 ( A )**

135 as shown in Table 1. It is assumed that it takes 3 minutes to load and unload a part on a pallet at load/unload  
136 station. The time to cross the distance between two consecutive MCs is assumed to be 0.5 minute. The  
137 arrangement of the FMC hardware is shown in Figure ??.

### 138 **8 Fig. 2 : Diagram of the Case Study**

139 Each machine is capable of performing different operations, but no machine can process more than one part at a  
140 time. Each part type has several alternative routings. Operations are not divided or interrupted when started.  
141 Set up times are independent of the job sequence and can be included in processing times. The scheduling  
142 problem is to decide the sequence of the jobs and which alternative routes should be selected for each job.

### 143 **9 IV. The Fuzzy Based Simulation Model**

144 Proposed approach of this research is to identify different scheduling parameters such as, processing time, due  
145 date and profit over cost for Job sequencing and processing time, travel time, work in que for routing and  
146 construct their membership functions and fuzzy rules. Using these membership functions and fuzzy rules a  
147 fuzzy inference system (FIS) is developed to identify the priority of jobs and to identify the best route using  
148 MATLAB fuzzy logic toolbox.

149 Three variables are selected to identify the job priority, named, processing Time In case of job sequencing, the  
150 variables of processing time, due date and profit over cost have three states each. The total number of possible  
151 ordered pairs of these states is 27. For each of these ordered pairs of states, we have to determine an appropriate  
152 state of variable job priority. A convenient way of defining all required rules is a decision table, which is given  
153 below. In case of route selection, the variables of processing time, work in queue and travel time have three states  
154 each. Similar to job sequencing, the total number of possible ordered pairs of these states is 27 and or each of  
155 these ordered pairs of states, we have to determine an appropriate state of variable route priority. The decision  
156 table is given below, V.

### 10 Global Journal of Researches in Engineering

### 11 The Experimental Result

Three jobs are considered here with three different processing times, due dates and profit over costs. They are determined based on customer requirements and the cost of the raw materials needed to finish the jobs. Processing time here is the ideal time, means time needed if it was machined in just one machine. The overall system comprises 4 different CNC machining centers (MCs), all capable of performing the required operations on each part type, a load/unload station and material handling system with one automated guided vehicle (AGV) which can carry one pallet at a time. The system produces three different part types, A, B and C. It is assumed that it takes 3 minutes to load and unload a part on a pallet at load/unload station.

### 12 Conclusion

The work presented in this paper was directed towards investigating the applicability of fuzzy techniques as a decision aid in the short-term control of flexible manufacturing systems. For this purpose a flexible manufacturing system for three jobs composed of four machines, one AGV, one load and one unload station and with routings and arrivals with fixed statistical characteristics was considered. A fuzzy scheduler for job sequencing and routing was developed. This scheduler uses fuzzy logic systems as well as fuzzy multiple attribute decision-making techniques. The thesis was done to increase performance by using fuzzy techniques and also in giving a systematic design procedure (lacking in the literature) that takes into account multiple objectives and needs no interface with linguistic directions from human experts (e.g., management).

In this research, hypothetical data are used to determine the job priority and routing. But, it would be more appropriate if actual data from a production system are used. Again, only job priority and routing are taken into account, some other criteria's can also be Volume XII Issue V Version I added. Several parameters are used to design the problem, but, yet there may be other parameters which can be added to make the model more accurate. Here, triangular membership functions were used. There are some other membership functions which could give different results. All possible rules are taken, but if more parameters were added, number of the rules would have been increased. All this changes may lead the model to better results.



Figure 1:

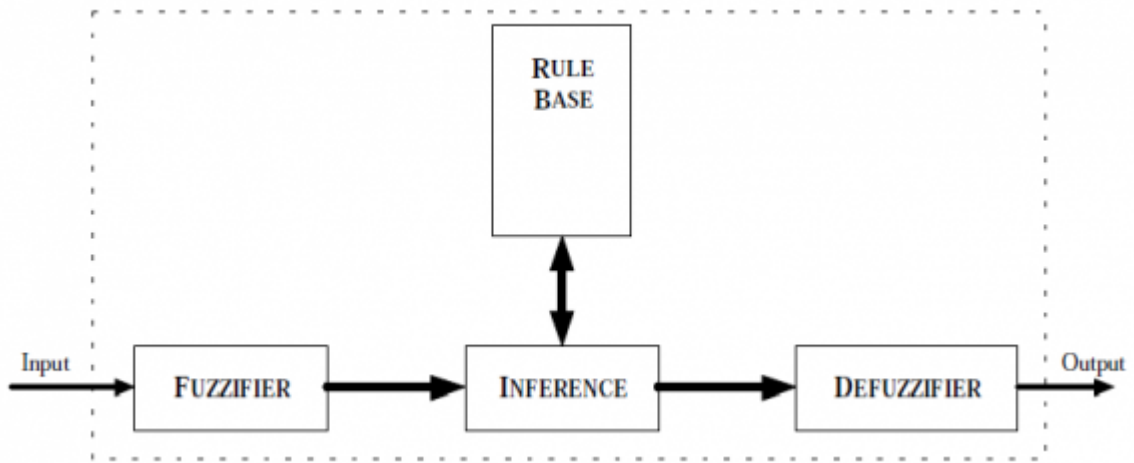
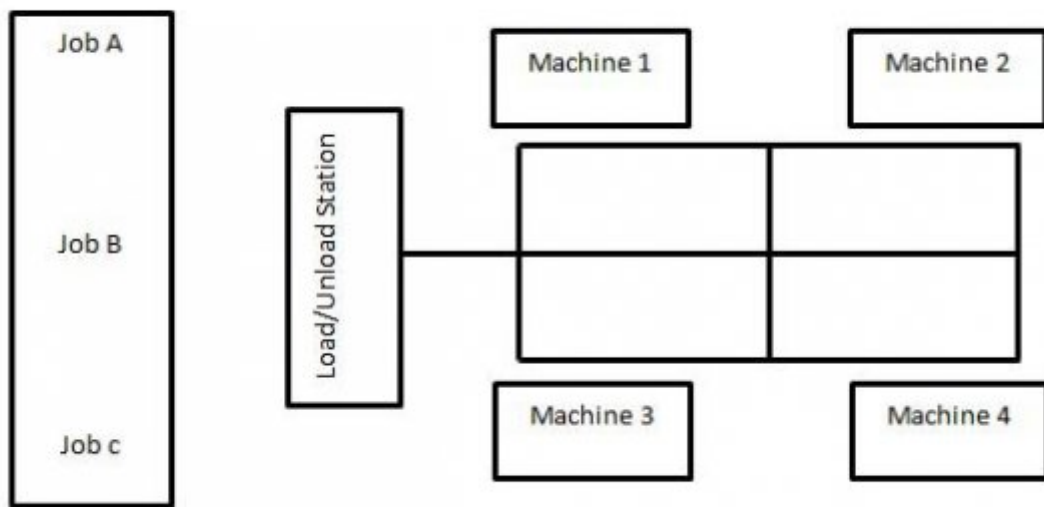
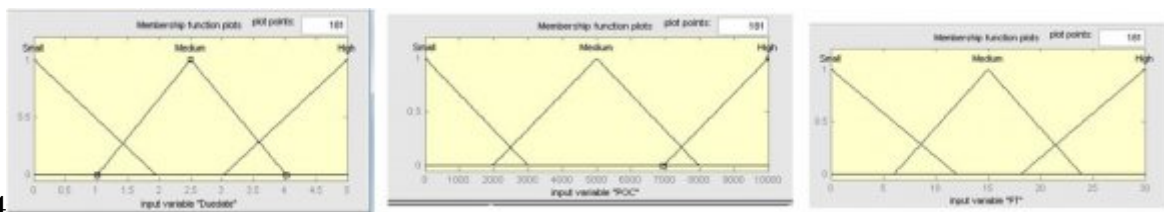


Figure 2:



3

Figure 3: Fig. 3 :



4

Figure 4: Fig. 4 :

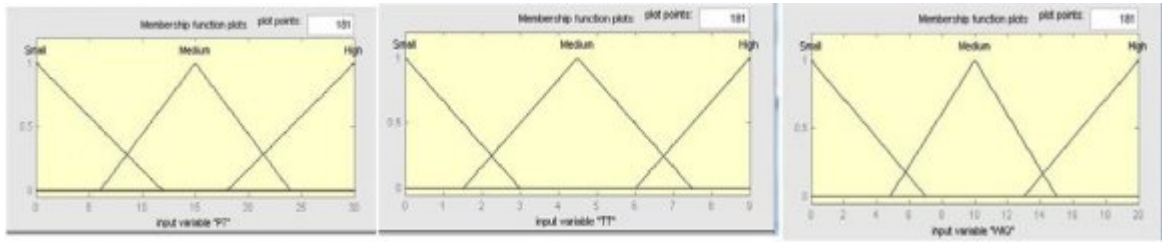


Figure 5:

1

Processing Time

Small Profit Over Cost Medium High

Due

Small

HI PH

MX

Small

Medium

PA HI

PH

Medium

High

AV PA

HI

High

Small

AV HI

PH

Small

Medium

LO NA

NA

Medium

High

NL NA

PA

High

Small

NA NA

NH

Small

Medium

NL NA

AV

Medium

High

MN NL

NA

High

The job priority criteria now used to derive fuzzy inference rules shown as an example :

27 If (Processing Time is High) and (Profit over Cost is High) and (Due date is Negative Average)

1. If (Processing Time is Small) and (Profit over Cost

is Small) and (Due date is Small) then (Priority is High)

2. If (Processing Time is Small) and (Profit over Cost is Medium) and (Due date is Small) then (Priority is Positive High)

.....  
??

Figure 6: Table 1 :

2

37

( A )

Global Journal of Researches in Engineering

Figure 7: Table 2 :

3

Job Name	Processing Time (Minute)	Profit over Cost (Tk)	Due (Day)	Date
A	17	6500	4	
B	19	6000	1	
C	8	4000	2	

Figure 8: Table 3 :

4

Job Name	Priority	Normalized Priority
A	0.375	0.223
B	0.708	0.422
C	0.593	0.355

Figure 9: Table 4 :

5

A Fuzzy-Multicriteria Based Approach for Job Sequencing and Routing In Flexible Manufacturing System (Fms)

.....

ear 2012

Y

38

( A )

Global Journal of Researches in Engineering

Machine	Job	Job	Job
1 2	A 6 2	B 5	C 7
3 4	7 2	5 3	1 1
		8	2

© 2012 Global Journals Inc. (US)

Figure 10: Table 5 :

6

Route Sequence)	(Machine	Work in Queue (In minutes)	Total Processing Time	Travel Time (Including Load/Unload time)
1-3-1-4		6	21	6.5
2-3-1-4		12	17	7
2-3-3-1		9	22	6

Figure 11: Table 6 :

6

Route Sequence)	(Machine	Total Process- ing Time	Travel Time (Including Load/Unload time)	Work in Queue (In minutes)
2-1-2-4		23	6	7
3-1-2-4		21	6	11
1-4-4-2		26	5.5	8

Figure 12: Table 6 :

7

Figure 13: Table 7 :

8

Route	Priority	Normalized Priority
1-3-1-4	0.584	0.387
2-3-1-4	0.5	0.331
2-3-3-1	0.425	0.282

Figure 14: Table 8 :

9

Route Sequence)	(Machine	Total Processing Time	Travel Time (Including Load/Unload time)	Work in Queue (In minutes)
1-3-3-2		10	5.5	8
1-4-3-2		11	6.5	6
1-2-3-4		11	5	9

Route	Priority	Normalized Priority
2-1-2-4	0.401	0.328
3-1-2-4	0.447	0.365
1-4-4-2	0.375	0.307

ear 2012  
Y  
39

( A )  
Global Journal of Researches in Engi-  
neering  
© 2012 Global Journals Inc. (US)

Figure 15: Table 9 :

10

Figure 16: Table 10 :

---

**11**

Route	Priority	Normalized Priority
1-3-3-2	0.534	0.313
1-4-3-2	0.658	0.385
1-2-3-4	0.516	0.302
Job	Route	
B	3-1-2-4	
C	1-4-3-2	
A	1-3-1-4	
VI.		

Figure 17: Table 11 :



- 
- 182 [Grabot (1993)] ‘A Decision support system for variable routings management in Manufacturing systems’. B  
183 Grabot . *Fuzzy Sets and Systems* 25 August 1993. 58 (1) p. .
- 184 [Guohua ()] ‘A Fuzzy Logic System for Dynamic Job Shop Scheduling’. Yen Guohua , BP , -C . 546-IV-551.  
185 *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics*, (the IEEE International  
186 Conference on Systems, Man and Cybernetics) 1999. IEEE. 4.
- 187 [Hintz and Zimmermann ()] ‘A method to control flexible manufacturing systems’. G W Hintz , H J Zimmermann  
188 . *European Journal of Operational Research* 1989. 41 p. .
- 189 [Watanabe et al. ()] ‘A Nonlinear Robust Control Using a Fuzzy Reasoning and Its Application to a Robot  
190 Manipulator’. K Watanabe , K Izumi , T Otsubo . *Journal of Intelligent Robotic Systems* 1997. 20 p. .
- 191 [Nahavandi and Solomon ()] ‘Application of Fuzzy Logic to Shopfloor Scheduling’. S Nahavandi , P Solomon .  
192 *Proceedings of Second New Zealand International Two-Stream Conference on Artificial Neural Networks and*  
193 *Expert Systems*, (Second New Zealand International Two-Stream Conference on Artificial Neural Networks  
194 and Expert Systems) 1995. IEEE. p. .
- 195 [Angsana and Passino ()] ‘Distributed Fuzzy Control of Flexible Manufacturing Systems’. A Angsana , K M  
196 Passino . *IEEE Transactions on Control Systems Technology* 1994. IEEE. 2 (4) p. .
- 197 [Tempelmeier and Kuhn ()] *Flexible Manufacturing Systems*, H Tempelmeier , H Kuhn . 1993. John Wiley and  
198 Sons.
- 199 [Jones et al. ()] ‘Intelligent scheduling for flexible manufacturing systems’. A Jones , L Rabelo , J S Tsai , Y  
200 Yih . *Proc. IEEE International conference on Robotics and Automation*, (IEEE International conference on  
201 Robotics and Automation) 1993. 3 p. .
- 202 [Narahari and Viswanadham ()] *Performance modeling of Automated Manufacturing Systems*, Narahari , N  
203 Viswanadham . 1992. Prentice Hall.
- 204 [Custódio et al. ()] ‘Production Planning and Scheduling using a Fuzzy Decision System’. L Custódio , J Sentieiro  
205 , C Bispo . *IEEE Transactions on Robotics and Automation* 1994. 10 (2) .