SAÜ Fen Bilimleri Enstitüsü Dergisi
4.Cilt 1. ve 2.Sayı (2000) 21-24

REDUCING LEAD TIME USING FUZZY LOGIC AT JOB SHOP

Emin Gündoğar * **Yavuz Burak Canbolat****

* *Department of Industrial Engineering Sakarya University Sakarya* ***-Turkey Email:gun@sakarya.edu.tr***
Department of Industrial Engineering Qafqaz University* ***Baku-Azerbaijan *E-mail: burakcanbolat@hotmail.com*

Key Words: Job shop scheduling, fuzzy logic, simulation of scheduling, lead time

ABSTRACT

One problem encountering at the job shop scheduling is minimum production size of machine is different from each another. This case increases lead time. A new approach was improved to reduce lead time. In this new approach, the parts, which materials are in stock and orders coming very frequently are assigned to machine to reduce lead time. Due the fact that there are a lot of machine and orders, it is possible to become some problems. In this paper, fuzzy logic is used to cope with this problem. New approach was simulated at the job sop that has owner 15 machinery and 50 orders. Simulation results showed that new approach reduced lead time between 27.89% and 32.36%.

I. INTRODUCTION

The job shop is the most widely used flexible production organization in our competitive environment (Gundogar, 1991). The job shop production control system should schedule the incoming orders in a way that does not violate the capacity constraint of individual workstations or processes (Narasimhan *et al.*, 1995). The scheduling problem can be defined as follows: N jobs are to be processed by M machines or work stations within given time period in such way that given objectives are optimized. Each job consists of specific set of operations, which have to be processed according to a given technical precedence order (Holthaus and Ziegler, 1997).

The general objectives of scheduling are to reduce tardiness, minimize work in process (WIP), set-up time, and average lead time, and maximize the utilization of machinery and worker capacity (Nahmias, 1993 and Chase *et al.*, 1998). In view of the fact that some objectives are conflicting, it is impossible to optimize all objectives. It is tried to find a good solution among these objectives (Nahmias, 1993).

Among the problems of operations research, scheduling is one of those having a lot of applications (Lee *et al.*, 1997). However practical optimal solution to scheduling problem hasn't been found yet (Fortemps, 1997). Because machine breakdown, maintaining, shortage of materials, quality problems and other problems make the manufacturing environment very complex. In addition, there is a conflict among scheduling objectives.

Approaches to scheduling problems are classified as optimal methods, heuristics and artificial intelligence applying (Gundogar, 1991, Aydın, 1997).

Although optimal methods find out an optimal solution to this problem, these methods can not be applied in practice (McKoy and Egbelu, 1999). Though heuristics and artificial intelligence approaches find out good solutions, these don't make sure optimal solution (Aydın, 1997). In practice, heuristics and artificial intelligence approaches are often preferred (Fortemps, 1997, Lee *et al.*, 1997, Holthaus and Ziegler, 1997).

There are a lot of studies about scheduling (Fortemps, 1997, Amar and Xiao, 1997); nonetheless there are a lot of problems that are unsolved. One of those problems is that high level of lead time that stems from different minimum production size of machine at the job shop.

Aim of this study is to process the parts, which come very often at slack machines for reducing lead time. This is the one of the basic aims of job shop scheduling.

The most important problem in new approach is that which parts should be processed at slack machines. This problem can be solved by decision mechanisms that make new method easy to achieve its aim. This decision mechanism was named as Assignment With Fuzzy Logic (AWFL). The factors that affect the designation of AWFL are minimum production size, level of WIP belonging previous operation, order frequency, load size of next machine, and level of WIP belonging related operation.

AWFL calculates the priority value reviewing up factors stated above. The part, whose priority value is maximum, is assigned to slack machine for to be processed.

In this paper, simulation was made at the job shop that has 15 machine and 50 orders to compare AWFL approach with traditional priority rules. Simulation results showed that new approach reduced the average lead time between 27.89% and 32.36% according to scheduling with traditional priority rules.

This study consists of five sections. Section 2 presents information about fuzzy logic; section 3 presents information about AWFL. In section 4, simulation was presented for both AWFL and priority rules scheduling. In section 5, simulation results and conclusion were presented.

II. FUZZY LOGIC

Lotfi A. Zadeh (1965) improved fuzzy logic. In a decade since from Zadeh's paper, a lot of theoretical studies relating to fuzzy logic were made in USA, Europe, and Japan. From middle 1970's to now, the biggest success that is related to applying fuzzy logic in practice is belong to Japan (Ross, 1995).

Fuzzy logic is a technique, which concern with statistical and uncertain vague source. Fuzzy logic was found on fuzzy set theory (Zhang and Huang, 1994).

Fuzzy set theory provides a natural platform to model fuzzy relationships such as " a little bit" and "too much" (Dundar, 1996). The basic elements of fuzzy logic can be presented follows:

- **Fuzzy Set:** A fuzzy set M of the universe X is characterized by a membership function μ_M, which takes its value in interval [0,1]. This new set can be called a fuzzy set because the membership of an element x to this set is vague and imprecise.

- **Membership Functions:** Membership function is used to define value of variable in fuzzy set. The value μ_M is called the membership function.

- **Fuzzy Operators:** Fuzzy operators carry out logical relations among fuzzy expression. Here, IF – THEN rules are used like expert system.

- **Fuzzy Inference:** Fuzzy inference maps an input space to an output space (Yu *et. al.*, 1999). The primary mechanism for doing this is a list of if-then statements, called rules, which are expressed in the form

If (antecedent) then (consequent).

In general, there are five steps in a fuzzy inference system: (1) Fuzzification of the input variables; (2) application of the fuzzy operators (AND or OR), if any, in the antecedent; (3) implication from the antecedent to the consequent; (4) aggregation of the consequences across the rules; and (5) defuzzification.

III. PROPOSED STUDY

A. Definition of Examining Problem

At the job shop scheduling, minimum production size of machines are different from each other. Whereas 200 units order can be opened to some machine, 5000 units order can be opened another. This case increases lead time.

This situation can be explained with an example as follows: Suppose 300 units order from part *A* arrived. Part *A* is processed at machines *K, X, Y,* and *Z* respectively. Minimum production sizes of part *A* that are opened *K, X, Y, and Z* are 7000, 3000, 300, and 200 respectively. The level of WIP is zero. In this situation, operational part sizes of part *A* which should be processed *K, X, Y,* and *Z* are 7000, 3000, 300, and 300 respectively. As seen from example, the level of WIP waiting machines *K,* and *X* are 4000, and 2700 units respectively. As understood from this example, lead time is very big.

In practice, due the fact that order arriving is stochastic and utilization of machines are changeable, average machines utilization is about 60% at the job shop. Some machines may be slack; the outers have a lot of jobs.

B. AWFL

New method improved in this study find out a different solution to problem stated above. With new method, the parts coming very frequently and that has enough WIP are processed at slack machines so that lead time reduces.

As stated earlier, the fact that there are a lot of machines and orders make finding optimal solution to scheduling problem difficult. In view of the fact that new method increases the problem existing at the job shop, it can't be implied effectively. In this paper, fuzzy logic was used so that new method can be used effectively at real job shop condition.

The fact that which parts should be processed slack machines is very important problem. This one can be solved a decision mechanism that make new method easy to achieve its aim. This mechanism was called AWFL. The factors that affect determining AWFL can be stated as follows:

- **Minimum production size of machine:** This shows units of minimum production size of machine. If number of part to be processed is less than minimum production size, it can't be assigned to slack machine.
- **Level of WIP belonging previous operation:** At the slack machine, WIP belonging previous operation, which equal or bigger than minimum production size can be processed.
- **Order frequency:** It is necessary that parts coming very frequently should be processed at slack machines. The value of order frequency was calculated as average weekly production size for simplicity.
- **Load rate of next machine:** One should pay attention load rate of next machine that process part. For simplicity, the load rate of next machine was calculated as the total operation time of the parts waiting for to be processed at the next machine.
- **Level of WIP belonging related operation:** AWFL, viewing the WIP level of related operation, give priority to the part that has minimum WIP.

In AWFL; fuzzy logic calculates the priority value viewing the factors stated above. The part, whose priority value is maximum, is assigned to slack machine to be processed. Simulation of AWFL was made at Matlab 5.0.

C. Construction of Fuzzy Inference System

In AWFL, Mamdani Type fuzzy inference system was used. "Minimum" was used as "AND" operator, "maximum" was used as "OR" operator, "minimum" was used at "implication stage", "maximum" was used " at the "aggregation stage", and "weighting central" was used at "defuzzifacation". System consists of 5 inputs, 1 output, and 29 rules.

D. Construction of AWFL's Membership Functions

Membership functions for 5 inputs and 1 output were shown in figures. Minimum production size, WIP belonging previous operation, WIP belonging related operation (Figure 1), and priority value (Figure 2) consist of "very little", "little", "middle", "much", very much" variables.

Load rate of next machine (Figure 3) and order frequency (Figure 4) consist of "little", "middle", "much" variables.

In this study, all of the membership functions consist of triangle function.

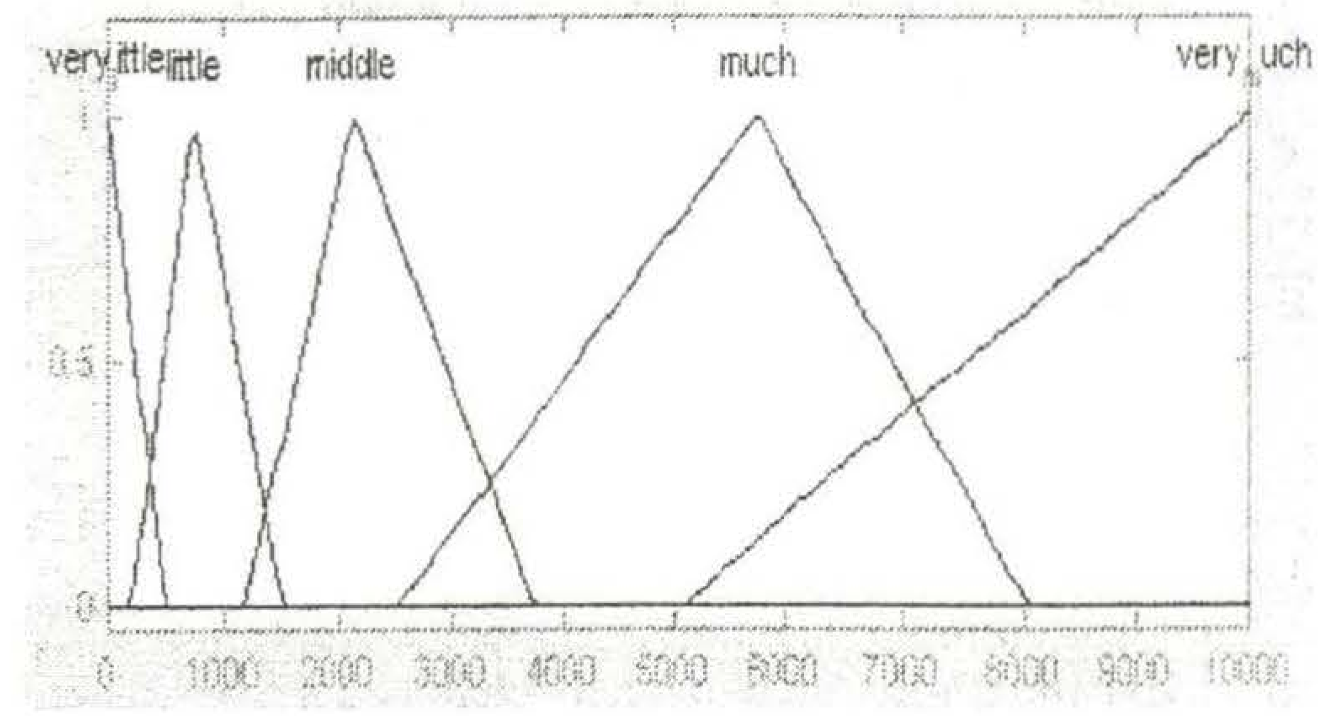

Figure2: Membership functions for output variable (priority value)

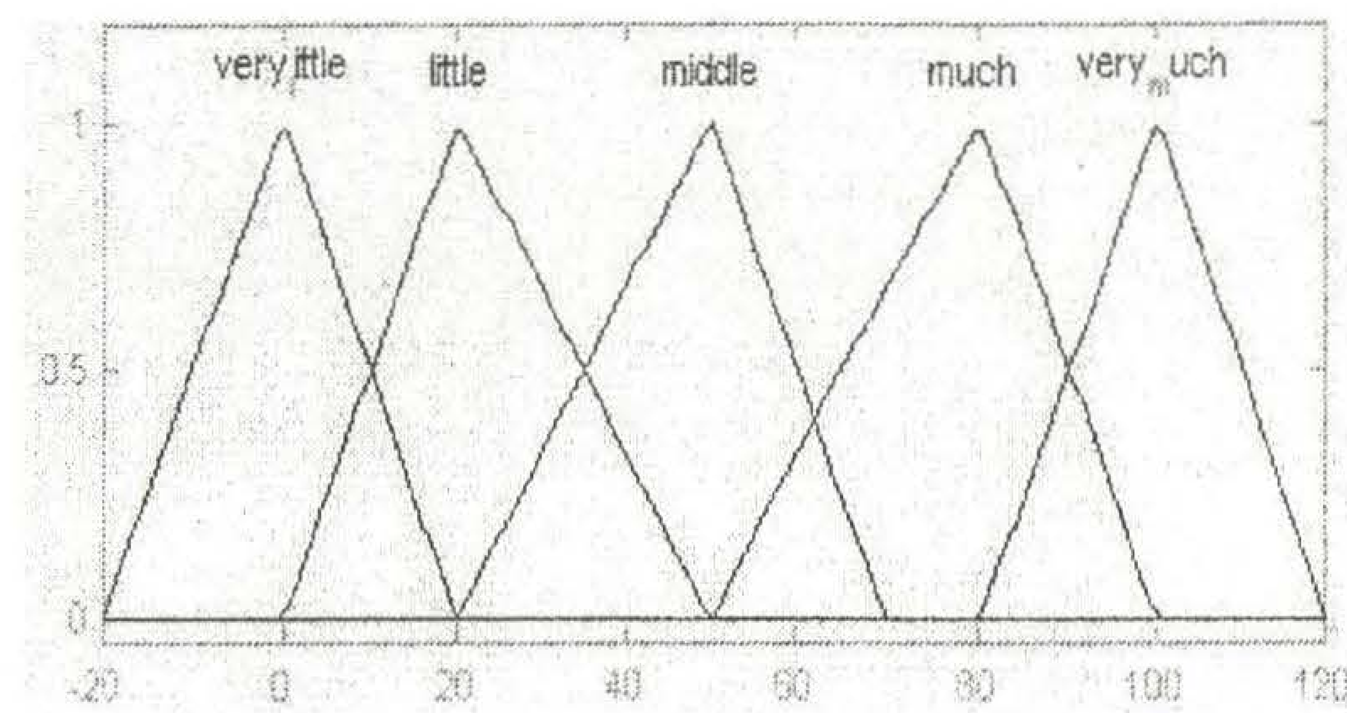

Figure 3: Membership functions for load rate of next machine

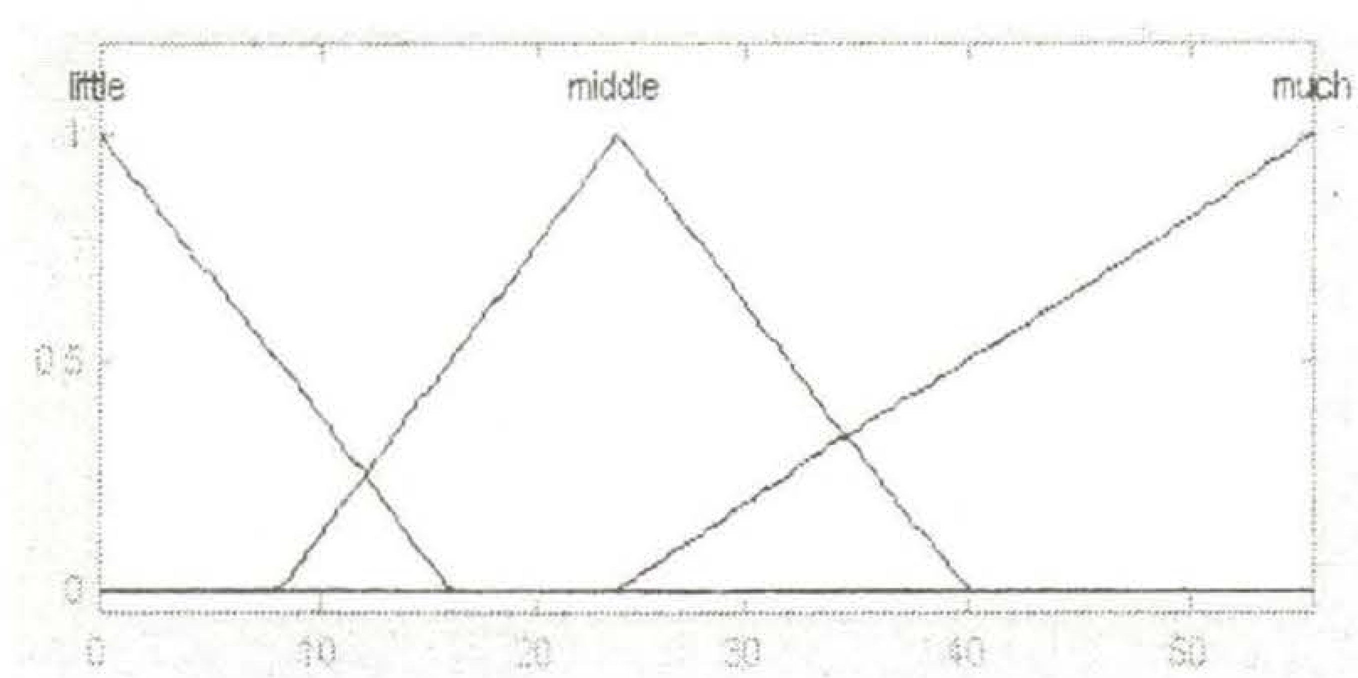

Figure 4: Membership functions for order frequency

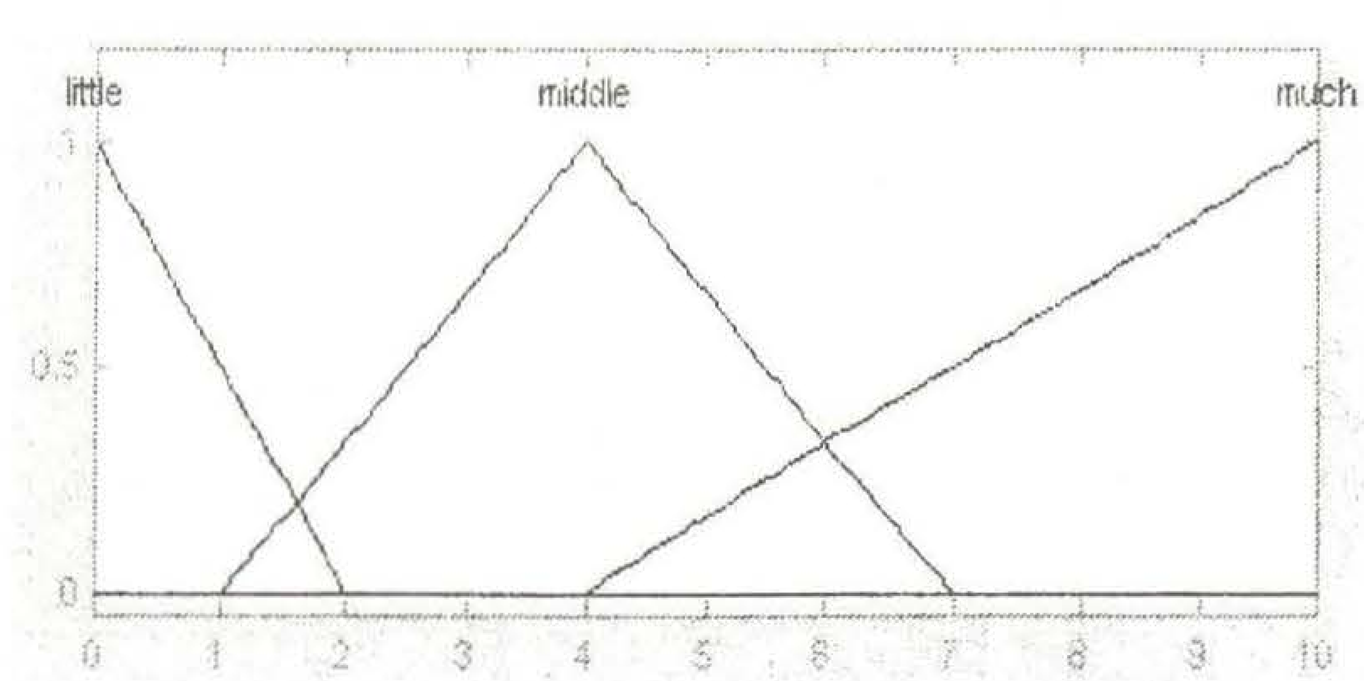

Figure 1: Membership functions for inputs with five variables

IV. SIMULATION

In this study, simulation program was written in Matlab 5.0 to compare with traditional priority rules and AWFL method. The general characteristics of job shop are follows: Scheduling was made as dynamic, forward and finite capacity. There are 15 different machines and 50 different parts whose operations numbers are between 3 and 6. Order arriving is stochastic. Simulation time is

Table 1 Simulation results

Priority rules	FCFS	FCFS-AWFL	CR	CR-AWFL	EDD	EDD-AWFL	MINSOP	MINSOP-AWFL	SPT	SPT-AWFL
Lead Times (days)	10.08	7.04	9.83	6.65	10.08	7.11	9.93	7.16	9.29	6.44

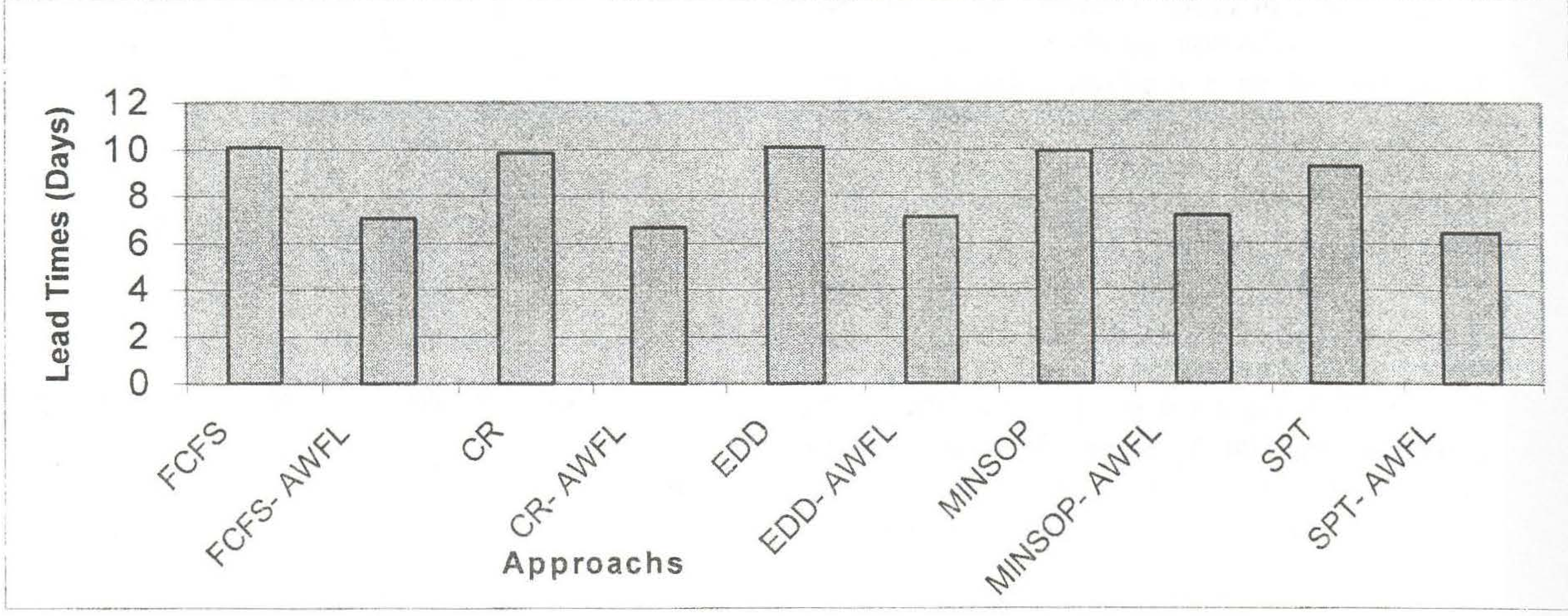

Fig. 4 WIP comparing with priority rules and AWFL

2400 hours. Simulation conditions of priority rules and AWFL are the same.

In this paper, simulation was made for both traditional priority rules such as FCFS, CR, EDD, MINSOP, and SPT and AWFL approach such as FCFS-AWFL, CR- AWFL, EDD- AWFL, MINSOP- AWFL, and SPT- AWFL.

V. CONCLUSIONS

Simulation results were presented at Table 1.

As understood from Table 1, AWFL approach reduced the average lead time between 27.89% and 32.36% according to scheduling with traditional priority rules.

Simulation results proved that AWFL approach showed better results than traditional priority rules did. Lead time comparing with AWFL and traditional priority rules was presented at Fig. 4.

New approach can be used a lot of aria such as calculating priority value, solving some problem occurring Just In Time (JIT) and Flexible Manufacturing System (FMS), measuring performance.

REFERENCES

AMAR, A.D. and XIAO, B., 1997, "Scheduling on a bottleneck station: a comprehensive cost model and heuristic algorithms", International Journal of Production Research, Vol. 35, No. 4, ss.1011-1030.

AYDIN, Mehmet Emin, 1997, Zeki Etmenlerde Ogrenme Kabiliyetinin Geliştirilmesi ve Bir Dinamik Atolye Tipi Cizelgeleme Uygulaması, Doktora Tezi, SAU Fen Bilimleri Enstitusu, Adapazarı.

CHASE, Richard B., AQUILANO, Nicholas J., JACOBS, F. Robert, 1998, Production and Operations Management: Manufacturing and Services, McGraw-Hill Companies.

CUSTÓDIO, Luis M.M., SENTIEIRO, João J. S. and BISPO, Carlos F. G., 1994, "Production Planning and Scheduling Using a Fuzzy Decision System", IEEE Transactions on Robotics and Automation, Vol. 10, No. 2, 160-168.

DUNDAR, M. Fahri, 1996, Bulanık Kumeler ve Endustri Muhendisligi Uygulamaları, Yuksek Lisans Tezi, İTU Fen Bilimleri Enstitusu, İstanbul.

FORTEMPS, Philippe, 1997, Job Shop Scheduling with Imprecise Durations: A Fuzzy Approach, IEEE Transactions on Fuzzy Systems, 5, 557-569.

GUNDOGAR, Emin,1991a, Atolye Tipi Uretim İcin Moduler Cizelgeleme ve Kontrol Paketi, Doktora Tezi, İTU Fen Bilimleri Enstitusu, İstanbul.