

Hierarchical of Fuzzy Expert System for Production Planning, Scheduling and Controlling System in Agile Environment

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Abstract: Production planning, scheduling and control are forms of decision-making, which play a decisive role in manufacturing as well as in agile production environments. In the current competitive environment, effective planning, scheduling and controlling has become a necessity for survival in the marketplace. In the last decade manufacturing companies decided to adopt intelligent solution, since the traditional manufacturing planning and scheduling mechanisms were found to be insufficiently flexible to respond to changing production styles and highly dynamic variation in production in product requirements. This paper presents a new hierarchical method for Production Planning, Scheduling and Controlling, and developed a Fuzzy Expert System for that based on a M. A. S. Monfared & J. B. Yang (2006) framework. The proposed model was implemented in door and window producer manufacture to illustrate the applicability of the new framework.

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Introduction:

Different approaches such as combinatorial optimization, artificial intelligence, simulation-based scheduling with dispatching rules, heuristics-oriented, and multi-criteria decision making are used for Planning, Scheduling and control. However, production planning, scheduling and control in dynamic production environment (i.e. in an FMS which are subject to limited resource, random machine failures or multi production criteria) is usually very complicated. Therefore, many agile manufacturing systems necessitate planning and scheduling for dynamically agile and unpredictable conditions; consequently, artificial intelligence and heuristic-based approaches have been considered in FMS planning and scheduling. In this area planning, scheduling and control system is best tackled by a synergy of the computer's planning and scheduling algorithms and the production planner's effective internal heuristics. In this "interactive planning and scheduling", the production planner is under control and can control the scheduling process through making use of experience and intuition with computer support. In other words, the system should act as a decision support system for production planner [J. Smed, et al. 2000]. Traditionally, decision on production planning, especially scheduling, was made through intuition, experience, and judgment. In the connection of the need of rapid response to uncertainty in scheduling and the increase in the speed of computers, it becomes increasingly important to explore alternative ways of obtaining better schedules within a short period of time. Fuzzy

logic, first introduced by Zadeh (1965), has been applied to many industrial problems such as production systems. Recently, there has been significant attention given to modeling scheduling problems within a fuzzy framework. The authors utilized this system in their method, as the fuzzy expert system can incorporate numerical results from a previous solution or simulation, and the scheduling expertise incorporates results of experiences or observations.

Our approach in this paper is to build a hierarchical fuzzy expert system for Production Planning, Scheduling and Controlling (PP&S&C) based on Monfared & Yang (2006) framework and integrate that with fuzzy approach to improve and actualize that.

This paper is organized as follows. The literature review and recent development is in Section 2.

Section 3 describe the definition of planning and scheduling problem, the new HFES approach for PP&S&C are presented in section 4. Section 5 contained the case study and implementation experience of method and finally concluding remarks and discussion are addressed in Section 6.

Literature review:

A number of applications of ESs to the area of production planning and scheduling have been developed and documented. The intelligent scheduling and information system (ISIS) was the first application of ES to job-shop scheduling (Fox and Smith, 1984). Hierarchical planning was used in ISIS to decompose complex problems into smaller

manageable pieces. The research with ISIS led to work on the development of the opportunistic scheduler (OPIS) (Ow and Smith, 1986), a knowledge-base factory scheduling system which uses problem decompositions to generate constraint-satisfying shop schedules.

The prototype expert priority scheduler (PEPS) (Robbins, 1985) is a rule-based ES which solves problems in shop floor control level, although its drawback is the fact that it is not able to recognize uncertainty and downstream data dependency.

To support product scheduling at a major petrochemical firm's refinery, a hybrid expert system (HESS) (Deal et al., 1992) was developed at the University of Houston. The knowledge base in HESS was developed to determine what products to produce at what time, and through which processors. HESS was developed using the EXSYS expert system shell and consists of approximately 400 production rules.

To schedule resources for the space transportation system, a management analysis resource scheduler (MARS) has been developed (Marsh, 1985). Chiodini (1980) developed an expert system for dynamic manufacturing rescheduling, which Biegel and Wink (1989) proposed an expert system for industrial job-shop scheduling.

De Toni et al. (1996) proposed an intelligence based production scheduler, which utilizes a hybrid push/pull approach. This scheduler uses some blackboard techniques of the type hypothesized by Hayes-Roth (1985). The production-scheduling blackboard consists of frames, lists and production rules, push a blackboard controller with a shop floor control system interface and codes/routings archives.

Custodio et al. (1994) discussed the issue of production planning and scheduling using a fuzzy decision system, while several outlines concerning the development of a rule-base for the specification of manufacturing planning and control system were recently made by Howard et al. (2000).

A fuzzy rule-based scheduler was proposed by Subramaniam et al. (2000), which dynamically selects, from several candidate dispatching rules, the most appropriate dispatching rule to employ, based on the prevailing job shop conditions. An expert system named KDPAG was built by Chen et al. (1998) applied to materials design and manufacture.

In addition, particular attention is also dedicated to the issue of effective rescheduling (Brown, 1989; Sarin and Salgame, 1989; Szelke and Kerr, 1994). Yamamoto and Nof (1985) suggested a Regeneration Method when they exploited production schedule expert system. Driscoll (1993) studied a knowledge based rescheduling expert system which was adapted to the flexible manufacturing environment, while Tayanlthi et al. (1992) proposed a knowledge-based

simulation system to analyze and handle the disturbances (including machine breakdowns and rush orders) in a flexible manufacturing environment. Recently a production rescheduling expert simulation system was also proposed by Li et al. (2000). This system integrates different techniques and methods, including simulation technique, artificial neural network, expert knowledge and dispatching rules and deals with four sources of production disturbances: (a) incorrect work, (b) machine breakdowns, (c) rework due to quality problems; and (d) rush orders.

Problem Definition:

As a literature review and from theoretical point of view, a planning or a scheduling problem is an optimization problem (or a resource allocation problem) within the range of availability and while some measures of performance are optimized. (whatever the resource might be e.g. time, machine, labor)(Monfared & Yang 2006). Metaxiotis and other define planning and scheduling forms of decision making, which play a crucial role in manufacturing. The process of selecting and sequencing activities in order to achieve one or more goals and satisfy a set of domain constraints is defined as planning. Scheduling is the process of selecting among alternative plans and assigning resources and time to the set of activities in the plan (Metaxiotis et al 2002).

The objective of scheduling in a FMS is the optimization of the use of resource to meet the overall production goals. Artificial Intelligence (AI), the technology that attempts to preserve domain intelligence (knowledge base) in order to use the same for decision making in the future, has matured enough to redirect the research in scheduling and has capabilities to be particularly suitable for scheduling (Kunnathure et al 2008). In this paper a hierarchical fuzzy expert system on the base of Monfared & Yang framework has been developed resolve this problem, and the new method implemented in a manufacturing company to illustrate its applicability and usefulness.

Methodology:

The hierarchical fuzzy expert system for PP&S&C, proposed in this paper is based on Monfared & Yang (2006) framework. Because most important variable in PP&S&C system have fuzzy nature, authors completed and actualized that method with fuzzy set theory. The advantage of the fuzzy logic system approach is that it incorporates both numerical and linguistic variable and has the ability to simultaneously consider multiple criteria and to model human experience in the form of simple rules. According to our research from literature this new method can help organization to cost by reducing the need for some personnel and reduction in time to

complete orders, preserve and disseminate scarce expertise throughout the organization, give better consistency to decision making, increase and improve

quality of product and more effective use of resources. (Metaxiotis et al 2002).

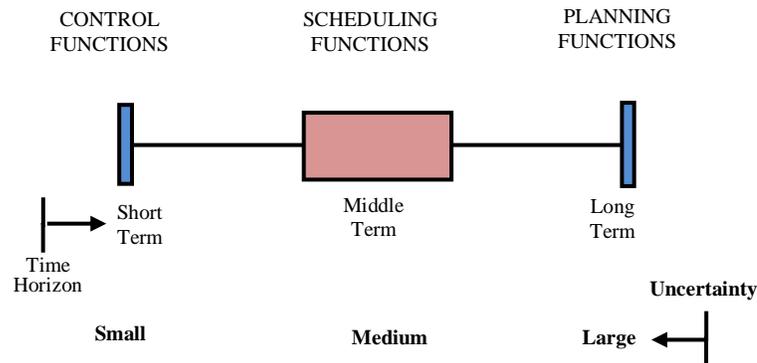


Fig. 1 Planning, scheduling and Control model

Monfared& Yang defined a new framework for PP&S&C and used that in automation. In their framework as in Fig. 1, time is used as an index of differentiation between planning, scheduling and control. Planning is concerned with the analysis and modeling of functions, which looks at a long time horizon ahead, whereas scheduling is concerned with the analysis and modeling of functions which looks at a short time horizon ahead. Control is concerned with the analysis and modeling of immediate actions in real time. Planning, therefore, is regarded as the right-hand side of Fig. 1 and its nature is more of a decision-making problem, whereas scheduling is regarded as the middle of Fig. 1, and its nature is more of an optimization problem, and control is regarded as the left-hand side of the chart depicted in Fig. 1. As in Fig. 1, uncertainty is also used as another index of differentiation between planning, scheduling and control. Both indices are counterpart towards each other, whereas the timing increases from shorter to longer, the uncertainty degrees associated with the functions also increases from smaller to larger. Here, the control functions are more certain than the scheduling and planning functions. As for design purposes, it is expected that the control functions are less trouble-making than those of scheduling and planning functions. (Monfared& Yang 2006)

In many real world applications, fuzzy systems that make use of the linguistic rules are well suited to describe the behavior of complex systems problems, which are difficult to model mathematically. Fuzzy theorists use fuzzy sets to represent the nonstatistical, uncertainty and approximate reasoning and apply to real life data. Thus, Zadeh (1965, 1978) extended the

bivalent indicator function I_A of the non fuzzy subset A of X , such that:

$$I_A(x) = 1(x \in A)$$

$$I_A(x) = 0(x \notin A)$$

to a multi valued indicator or membership function in which the membership function maps each element x in X to a real number in the interval $[0,1]$. The function value $m_A(x)$ then represents the grade of membership of x in A .

The larger $m_A(x)$, stronger the grade of membership for x in A . The membership function can typically take linear or nonlinear forms including left-triangle, right-triangle, triangle, Gaussian and sigmoid functions. Each membership function is determined by two values: the start point x_1 , and the end point x_2 . Each fuzzy variable can have any number of fuzzy sets and each set can be either linear or nonlinear form of membership functions. In an n -input-single-output fuzzy system, the fuzzy rules have the following general format: (Fain et al 2004)

$$R_j : \text{IF } X_1 \text{ is } Y_{1,j} \text{ And } X_2 \text{ is } Y_{2,j} \\ \text{And} \dots \text{And } X_n \text{ is } Y_{n,j} \text{ Then } Y \text{ is } Z_j$$

In the new proposal model as in Fig. 2, for designing an effective hierarchical model for PP&S&C, We used four fuzzy expert systems, which three of them work in three decision level, (Planning, Scheduling, and Controlling) and work parallel with each other. They sent their result to the forth fuzzy expert system to have a crisp output for ranking the orders. This model includes several steps. There are:

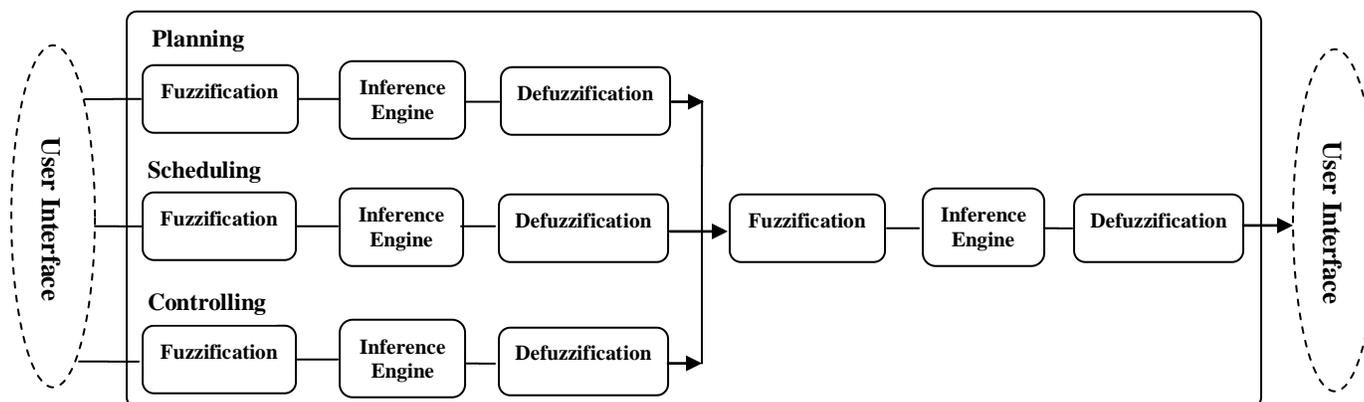


Fig. 2. Hierarchical Fuzzy Expert System

1. Interview & Review:

In first step for acquiring effective fuzzy factor in orders priority we review literature on critical factor for PP&S&C and review with expert and managers in 3 steps. We are using this interview to acquire their experiences for transferring to system. These three steps include three decision levels, which are:

I. Planning:

Effective and critical factor in this level are those factors, that effect long term (annually) planning of manufacture. For acquiring these factors, we have to interview with directorate and production manager and other managers who specify production policy of manufacture to acquire effective fuzzy factor.

II. Scheduling:

In this level we use experiences of production director and production manager of different section. By interviewing with them we have to find effective factor in decision making of order priority in scheduling level. Decision making in this level is done in monthly period and in order to consider the internal and external changes in environment, the factors should be upgrade monthly.

III. Controlling:

This level is the lowest level of decision making for production, and for acquiring effective and critical factor in this level, it is needed to interview with production manager of different section and other person, who involve in production. We should use their experience for decision making for sending the orders into production line. This level is adopted with weekly decision making of manufactures and in order to consider the internal and external variant condition, and increasing the efficiency of model, the factors should be updated weekly.

2. Fuzzification:

Fuzzification is a kind of process in which the input data, precise or imprecise, is converted into a kind of linguistic form, which is easily perceptible by the human mind.

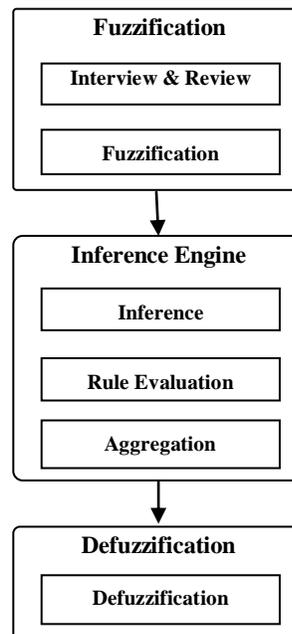


Fig. 3 Fuzzy Expert System

3. Inference:

setting the “if ... and ... then” rules. For each rule, one fuzzy subset is assigned to each output variable. Usually, it relates to fuzzy logic AND or fuzzy logic OR.

4. Rule Evaluation:

The real input number, called readings are translated to proper terms of the corresponding linguistic variables.

5. Aggregation:

Choosing control action as an output of the application of a control rule; it relates to fuzzy logic MAX or fuzzy logic SUM.

6. Defuzzification:

also known as decoding the output; this operation produces a nonfuzzy control action presenting the membership function of an aggregated fuzzy action in the form of a single crisp value. Several methods can be used for defuzzification such as methods of maximizing, the average heights, center-of-gravity (COG) method, etc.

Case Study:

The model presented in this paper is implemented in Maral-Darb Co. which produces two-walled windows for buildings. This company includes three production sections which are inter-related. In order to implement the hierarchical fuzzy expert system, first we interviewed with managers of its different sections in order to identify the critical factors, and to define membership functions and fuzzy sets.

In this paper, a total of four Fuzzy Expert Systems with each system having three input variables and one output variable have been considered. The variables of each level are:

I. Planning:

- i. *Profit*: which order have high profit for manufacture.
- ii. *Production amount*: which order increase the manufacture production.
- iii. *Market share*: which order acquired new internal and external marketplace.

II. Scheduling:

i. *Profit*: which order have high profit for manufacture.

ii. *Customer*: Which customers have good background and is profitable for manufacture.

iii. *Keep production line working*: assurance from secured of raw material and prevent from evacuating of production line.

III. Controlling:

i. *EDD*: which order has earliest due date.

ii. *Customer*: Which customers have good background and is profitable for manufacture.

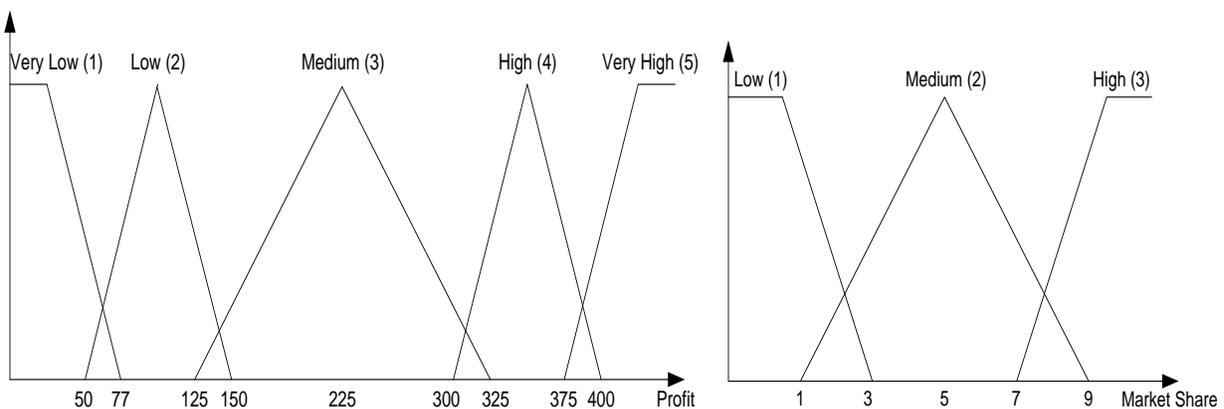
iii. *Production amount*: which order increase the manufacture production.

Fig.4 illustrate the fuzzy sets membership functions of each variable.

The fuzzy sets corresponding to each input/output can be represented by the integers 1-5 or 1-3. The 0 can be used to represent the variable has no effect to the object. The rule base of second level system with shown in the Table 1.

Conclusion:

FESs are becoming more and common decision-making tools in many organizations and The finding of this survey shown that FESs are generally perceived to be very useful in production planning and scheduling. In this paper, a new approach based on a hierarchical fuzzy expert system for production planning and scheduling was developed and implemented in the manufacture to illustrate the applicability of the model.



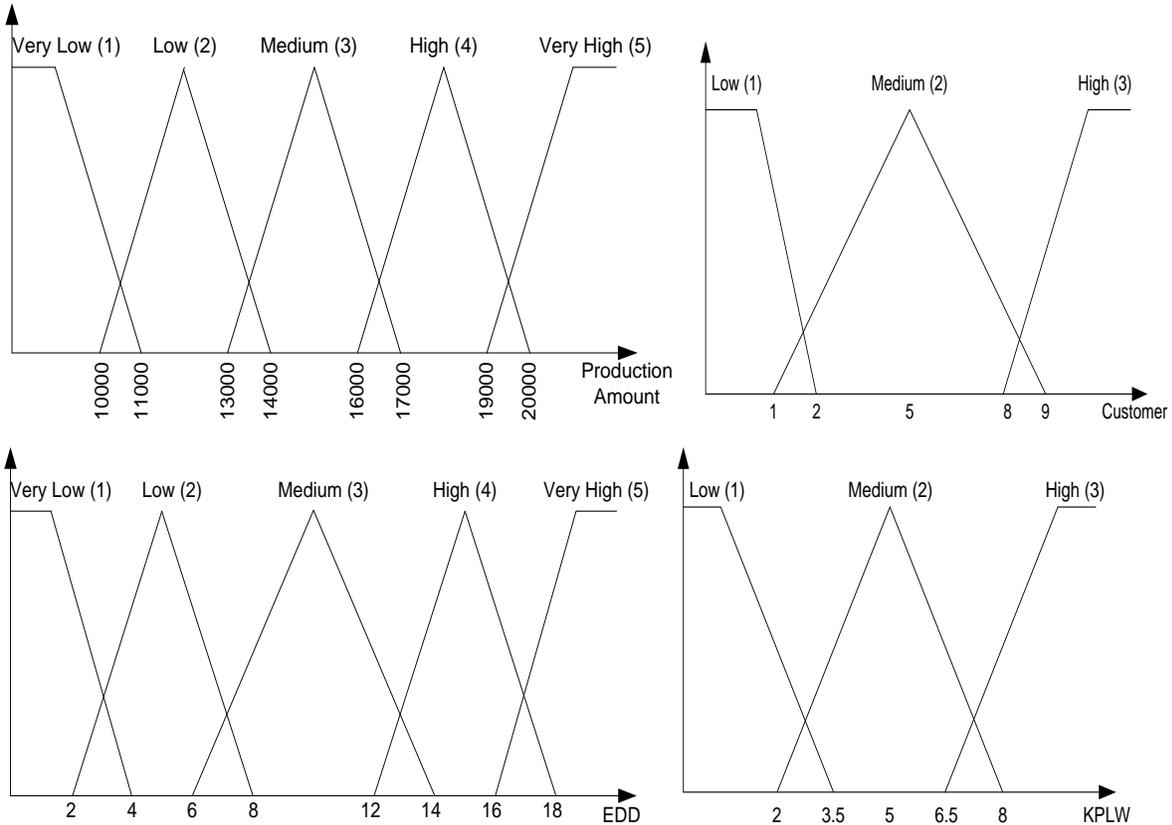


Fig. 4 Membership Function

Table1: Rule Base

Prifit	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2	1	1	1
Cusmert	3	3	3	2	2	2	1	1	1	3	3	2	2	2	1	1	3	3	2	2	1	1	3	2	1	3	2	1	
KPLW	3	2	1	3	2	1	3	2	1	3	1	3	2	1	3	1	3	1	3	1	3	1	3	3	3	3	3	3	
Output	5	4	3	4	3	2	3	2	1	4	3	4	3	2	3	2	4	3	3	2	2	1	3	2	1	2	2	1	

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