

Fuzzy Expert System for the Competitiveness Evaluation of Shipbuilding Companies

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Abstract—The world's shipbuilding industry as well as shipping industry is going through some unprecedented recession period in recent years. Shipbuilding companies in China have suffered a lot and many are now focusing on improving their competitiveness to survive the recession. The evaluation of a company's competitiveness is difficult considering the high level of uncertainty involved. This paper is a preliminary attempt to evaluate the competitiveness of Chinese shipbuilding companies using Fuzzy Expert System. An example system is presented in this paper which has shown its adoptability. With a larger and better intelligent database system established in the future, more accurate and reliable results can be achieved, which could help the practitioners in the shipbuilding industry to better understand and predict their companies' competitiveness.

Index Terms—Fuzzy Expert System, Competitiveness Evaluation, Shipbuilding Company, Chinese Shipbuilding Industry

I. INTRODUCTION

Due to the influences of global financial crisis, the international economic depressions struck the shipping market and also caused a depression in the shipbuilding industry. As one of the world's top three largest shipbuilding countries, China has suffered a lot in its shipbuilding industry and related economic departments. New orders shrunk and hundreds of shipbuilding companies in China are having difficulties in funding. For a shipbuilding company, its competitiveness is the key factor to survive the recession. Thus, it is of great importance to effectively evaluate the companies' competitiveness and then find ways to survive the crisis.

The leader of the shipbuilding industry has been shifting ever since 1850 with the development of international economy. The United States once played an important role in the industry more than a hundred years ago. The UK and Western European shipbuilding industry fell in the 20th century but its shipping industry raised and is still in a dominant position today. Japan refocused its manufacturing industry when its leadership

in the shipbuilding industry was to be taken by South Korea, and now South Korea is the largest and strongest shipbuilding country in the world. It is believed that the shipbuilding center is moving again in the 21st century, to Southeast Asia and East Asia countries including China. China first stood at the third place of the world's shipbuilding industry in 1995, and has remained at the second place to South Korea since the 21st century. China has grown to the leading position of the three major indicators (Ship Deliveries, New Ship Orders, and Booked Ship Orders) of the world's shipbuilding market share since the year 2010, but barely stayed at the position in the following years, as shown in figure 1. For most of Chinese shipbuilding companies, the amount of new ship orders is on a declining trajectory in the year 2012, and now (first quarter of 2013) it is becoming even worse.

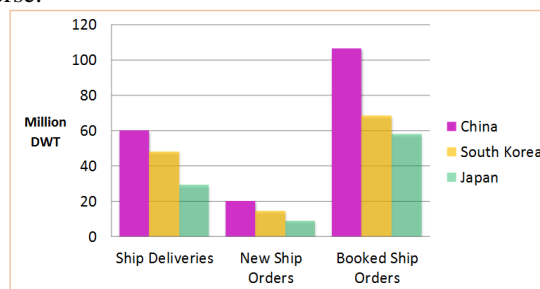


Figure 1. Three major indicators of the world's shipbuilding market share in 2012. Data from China Association of the National Shipbuilding Industry (CANSI)

One of the most important factors of a customized manufactory company such as a shipbuilding company's competitiveness is the how many New Orders the company is capable to get. The amount of orders reflects the degree of recognition a company received from the market, and will influence the company's sales and profits. Thus, it is critical to forecast the orders and keep abreast of its fluctuation in order to make developing strategies, investing plans, and to improve the company's competitiveness.

It is difficult to evaluate a company's competitiveness in consideration of the high level of uncertainty involved, which includes unclear input information and indefinite decision criteria. Fuzzy expert system designed by expert knowledge has been used to solve similar problems in many fields [1], [2], [3], and it is not only suitable but also advantageous to analyze this kind of systems.

II. COMPETITIVENESS OF SHIPBUILDING COMPANIES

A. The Competitiveness of a Company

Competition has become one of the most important issues for all the companies and governments today, and it is the same situation in the shipbuilding industry which is influenced by the global economic depression [4]. Nowadays, the era when competition was driven mainly by input costs is going to an end, which means companies could not enjoy a competitive advantage driven by a single endowment such as natural resources, large investment, or inexpensive labor any longer.

The competition in modern shipbuilding industry is more complex and dynamic, and requires continual innovation to make more productive use of inputs. Apart from the cost, companies' competitiveness is also dependent on their technology, the quality of their products, the ability in researching and developing new types of products, and their profit margin. In the shipbuilding industry particularly, South Korea, Japan, and China all have their different sources of competitive advantage in terms of cost structure, level of shipbuilding technology, quality standards, delivery time, and financing capability.

Much research has been done on the competitiveness of a company and many evaluation systems with indicators have been established. Normally the indicators include: Ship deliveries, Manufacturing efficiency, New orders, Booked orders, Sales, Facilities, and Investment in R & D. These factors are believed to be a group of typical competitiveness indicators of shipbuilding companies.

B. Critical Factors of Shipbuilding Companies

In China, there are several kinds of shipbuilders such as state-owned companies, private companies, foreign direct investment companies, etc., and their performance during an economic turbulence could be quite different. Shipbuilding is a typical customized manufactory industry, in which a company's ability to win new orders basically reflects the degree of recognition from the market that the company received, and in a way defines its competitiveness.

Most of existed researches are either using Experts Opinion Method that collects marks which are given by experts, or using Evaluation Indicators System that also requires experts giving marks on each indicator and the weight distribution, which are mainly qualitative analyses and could overlook some important factors which influence the companies' competitiveness. A shipbuilding company's Orders can be affected by various factors such as the world economic environment, the development of

international trade, the company's location, the amount of invested capital, the labor, and the types of ships the company can manufacture. Considering this complicated and volatile situation, we tried to design an expert system based on fuzzy model to forecast the possible amount of Orders of a certain shipbuilding company, given a series of variable values.

III. FUZZY EXPERT SYSTEM

A. Fuzzy Reasoning Theory

The Fuzzy logic method was first put forward in 1965 by Lotfi Zadeh [5], who created the fuzzy set theory and put it into practice. Fuzzy logic is a form of many-valued logic which deals with reasoning. In contrast with traditional logic theory, the fuzzy logic is approximate rather than fixed and exact. In traditional logic, the binary sets have two-valued logic, i.e. true or false, while in fuzzy logic, the variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely false and completely true. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions.

Fuzzy logic is conceptually and formally different from the fundamental concept of probability theory [6]. Probability theory considers not facts but events that will either occur or not occur. Fuzzy logic focuses on degrees of truth such as fuzziness, partial or relative truths, and tries to capture the essential property of vagueness. Fuzzy logic uses Fuzzy Membership Function to describe fuzzy sets that map from one given universe of discourse to a unit interval. Several operators are defined in Fuzzy Inference System which uses feed forward and backward inference methods to identify which aspects of the conditional rules are fulfilled [7]. The operators include Aggregation operator for fulfillments of the rules according to their initial conditions; Implication operator for computing the severities of fulfillments; and the Accumulation operator for accumulation of inferences among the fulfilled rules. A fuzzy logic based model uses a set of if-then rules and logical operators to establish a relationship between the input variables and the outputs.

B. Fuzzy Set

In the basic concepts about fuzzy sets and their notation and terminology, a crisp set A (which is a classical non-fuzzy set) can be defined by a "membership function" μ_A , which can assume only the values 0 and 1: for each $x \in X$, when $\mu_A = 1$, x is declared A , and when $\mu_A = 0$, x is declared as a non-member of A [8], [9]. However, concepts very often contain some vagueness that does not allow dividing elements in such a sharp way between two groups in the natural language, members and non-members. This vagueness could mathematically be represented by allowing the characteristic function to assume all values between 0 and

1, so expressing different grades of membership of each element $x \in X$ in A .

A fuzzy set can also be fully and uniquely represented by its α -cut besides the membership function. Given a fuzzy set defined on X , an α -cut is the crisp set that contains all the elements of X whose membership grades in A are greater than, or equal to the specified value of α . A convex, normalized fuzzy set A defined on the set of all real numbers R is called a fuzzy number if the fuzzy set has the following three properties: (1) A is a fuzzy set whose largest membership grade is 1, (2) the α -cut of A for every $\alpha \in (0, 1]$ are closed single intervals, and (3) the strong α -cut for $\alpha = 0$ is bounded.

Fuzzy arithmetic consists of performing arithmetic operations on fuzzy numbers in terms of arithmetic operations on their α -cuts, i.e. on closed intervals, using the rules and the notations of an area of classical mathematics called "interval analysis". Basically, the endpoints of the α -cuts, on which the operation has to be performed, must be combined according to the operation. The minimum and maximum values of the solution will define the lower and upper endpoints of the solution interval, respectively.

C. Fuzzy Expert System

A fuzzy expert system is a collection of membership functions, rules and logical operators that are used to establish a relationship between the input and the output variables. Unlike conventional expert systems, which are mainly symbolic reasoning engines, fuzzy expert systems are oriented toward numerical processing.

Generally, a fuzzy expert system consists of fuzzy rule base, fuzzy inference engine, fuzzifier and defuzzifier. A fuzzy rule base consists of a set of fuzzy IF-THEN rules. It is the core of a fuzzy expert system. In order to develop the rules for a fuzzy expert system, information can be collected either by investigating experts or by collecting relevant data, or both. The Fuzzy inference engine relates the consequences of the linguistic rule base with membership function values to deduce the output for the corresponding input values. In this paper, the Mamdani inference scheme will be used in the following case to evaluate the competitiveness of shipbuilding companies in China.

IV. CASE STUDY: EVALUATION OF THE COMPETITIVENESS OF SHIPBUILDING COMPANIES

A. Identification and Definition of Variables

The preparation and preprocessing of data are necessary before the constructing of the fuzzy expert system. As a start, the authors first researched the influences by the company's natural endowment, and despite the time factor, which means we will not consider the variables such as world economic environment.

Six main factors of a shipbuilding company are concluded that would affect the Orders that a company can receive, namely: the company type, company located area, the city's GDP, population, the ship types, and the invested capital of the company. They are Inputs of the model and each of them has different fuzzy partitions and corresponding fuzzy linguistic variables.

As we mentioned above, there are different company types in China and it is an important factor to the company, in the shipbuilding industry, most companies can be grouped into three types: private companies, local companies and large state-owned companies which we use "country" to represent. As for the area that the company located in, most of the shipbuilding companies in China have formed three clusters in the Pearl River Delta, Yangtze River Delta, and Bohai rim region. We selected several most representative ship types and classified them into four groups: Panamax ship, Multipurpose ship, Container ship, LPG and LNG, they represent ships with different values and manufacturing technology difficulties. The LPG and LNG ships are classified as one type because of their high added value and high technology. The outputs which represent the orders are classified into five levels: very small, small, medium, large and very large. All of the inputs and outputs are listed in Tab. 1.

TABLE I. INPUTS AND OUTPUT OF THE SYSTEM

Inputs					
ComType	Private	Local	Country		
Area	Pearl	Yangtze	Bohai		
GDP	Low	High			
Population	Small	Medium	Large		
ShipType	Panamax	Multipurpose	Container	LPG/LNG	
Capital	Little	Middle	Big		
Outputs					
Orders	VS	S	M	L	VL

B. Determination of Membership Functions and Reasoning Matrix

There are normally two inference methods for fuzzy expert system, namely the Mamdani inference method and the Takagi-Sugeno-Kang (TSK) method. The essential differences between these two methodologies are the formats of the results. The result of Mamdani inference is one or more fuzzy sets which must then be defuzzified into one or more real numbers, while the result of TSK inference is one or more real functions which may be evaluated directly. Thus the choice of inference methodology is linked to the choice of defuzzification method.

According to expert opinions and investigation questionnaires, the input and output Fuzzy Membership Functions are created. For the case study of this paper, the authors have interviewed many experts in the shipbuilding industry including managers of shipbuilding companies, officers in related government departments, researchers in ship classification societies, etc., and the

authors also investigated several shipyards to learn more information.

The input Fuzzy Membership Functions designed in this case study are showed in Fig. 2 and the output Fuzzy Membership Functions are in Fig. 3.

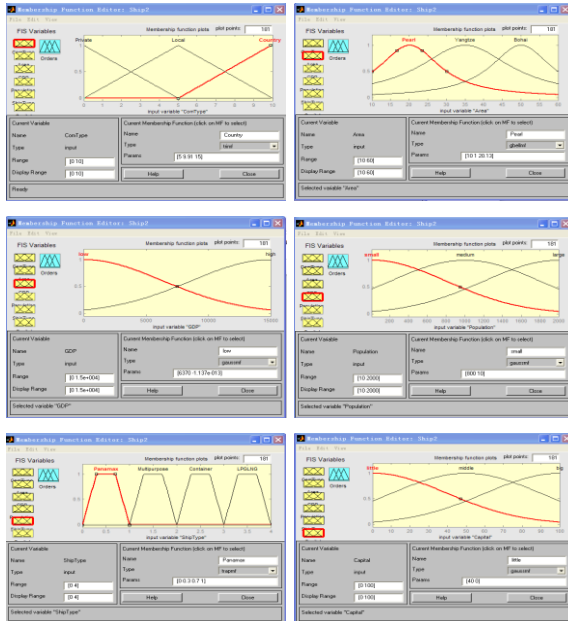


Figure 2. Inputs Fuzzy Membership Functions

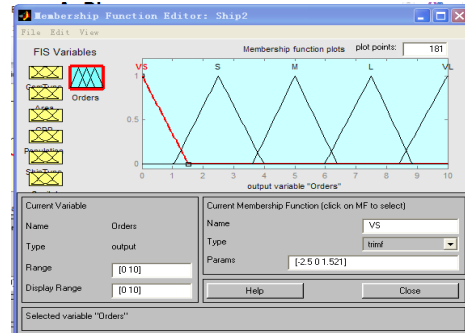


Figure 3. Output Fuzzy Membership Functions

C. Representation of Data and Construction of Fuzzy Rules

The determination of the rules to be used is usually the most difficult and time consuming step during the whole process. In this case study, eleven typical shipbuilding companies which could in a sense represent most types of the companies within the shipbuilding industry in China are chosen from Chinese shipbuilding industry yearbook [10], and then the fuzzy rules for the expert system are constructed based on these real data.

In the chosen eleven shipbuilding companies, the company type covered private company, local company and the state-owned company which is represented by "ComType" in the inputs. And the selected companies' locations covered all of the three main shipbuilding clusters in China. The list of rules is showed in Fig. 4.

1. If (ComType is Country) and (Area is Yangtze) and (GDP is high) and (Population is large) and (ShipType is Panamax) and (Capital is middle) then (Orders is VL) (1)
2. If (ComType is Private) and (Area is Bohai) and (GDP is low) and (Population is medium) and (ShipType is LPG LNG) and (Capital is little) then (Orders is S) (1)
3. If (ComType is Private) and (Area is Yangtze) and (GDP is low) and (Population is small) and (ShipType is Container) and (Capital is little) then (Orders is VS) (0.8)
4. If (ComType is Private) and (Area is Yangtze) and (GDP is high) and (Population is large) and (ShipType is LPG LNG) and (Capital is middle) then (Orders is L) (0.9)
5. If (ComType is Local) and (Area is Pearl) and (GDP is high) and (Population is medium) and (ShipType is Container) and (Capital is big) then (Orders is M) (1)
6. If (ComType is Private) and (Area is Bohai) and (GDP is low) and (Population is small) and (ShipType is Panamax) and (Capital is little) then (Orders is S) (0.9)
7. If (ComType is Private) and (Area is Yangtze) and (GDP is low) and (Population is medium) and (ShipType is Multipurpose) and (Capital is little) then (Orders is VS) (0.8)
8. If (ComType is Private) and (Area is Yangtze) and (GDP is low) and (Population is small) and (ShipType is Multipurpose) and (Capital is big) then (Orders is L) (0.8)
9. If (ComType is Private) and (Area is Yangtze) and (GDP is low) and (Population is medium) and (ShipType is Panamax) and (Capital is little) then (Orders is VS) (0.8)
10. If (ComType is Private) and (Area is Yangtze) and (GDP is low) and (Population is small) and (ShipType is Multipurpose) and (Capital is little) then (Orders is S) (0.8)
11. If (ComType is Private) and (Area is Pearl) and (GDP is low) and (Population is small) and (ShipType is Container) and (Capital is little) then (Orders is M) (0.8)

Figure 4. List of Fuzzy Rules for the Fuzzy Expert System

D. Discussion and Evaluation of the Results

A flow scheme of Fuzzy Expert System for competitiveness evaluation is designed as Fig. 5, which shows how this fuzzy expert system for this case study works. The expert knowledge can be collected by analyzing results of survey questionnaires and interviewing professionals in the shipbuilding industry. The fuzzy rules are defined based on real data from yearbook of the shipbuilding industry. With enough rules, the expert system can give results of output which representing the orders when given a certain set of input

which representing a shipbuilding company's situation. The rules can be added at any time when having more real data, and with more fuzzy rules, the system will give more accurate output results.

The fuzzy expert system can be evaluated by comparing the obtained output with the real data. After constructing this system, the authors tested it by comparing the result calculated by the system and the historical data of several shipbuilding companies other than the ones have been selected for the fuzzy rules. For example, we input the data which describe the situation of Yantai Raffles Shipyard Co Ltd., and the result which

the fuzzy expert system gives is 3.89, which represent 170000, while the real data of Yantai Raffles Shipyard's order is 174397. This means the system works effectively. The tested example is showed in Fig. 6.

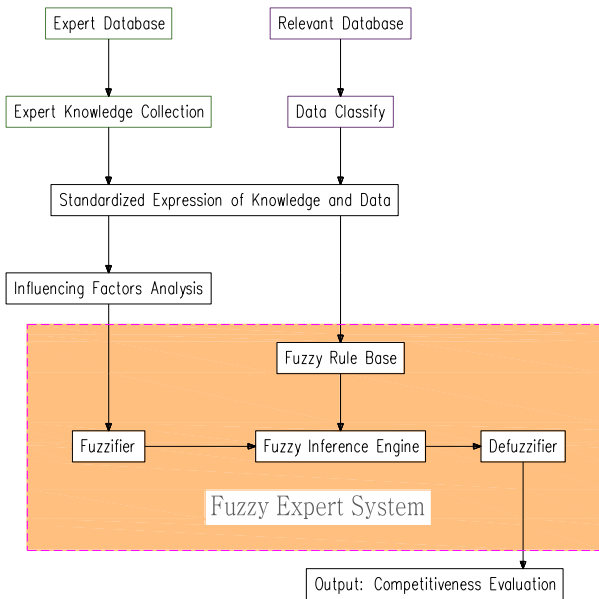


Figure 5. Flow Scheme of Fuzzy Expert System for Competitiveness Evaluation

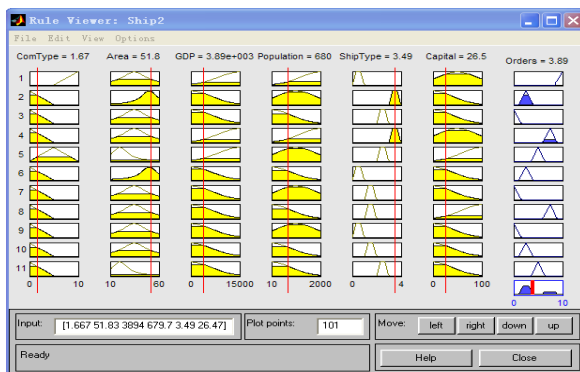


Figure 6. The tested example of Yantai Raffles Shipyard Co Ltd.

V. SUMMARY AND CONCLUSIONS

This paper is a preliminary attempt to evaluate the competitiveness of Chinese shipbuilding companies using Fuzzy Expert System. Many parts of the reality is various and complicated, when exact data are difficult to get, fuzzy expert system designed by expert knowledge is a reasonable alternative to analyze systems with high level of uncertainty. The output of a company's competitiveness evaluation is usually expressed by linguistic value such as "high", "medium", or "low". Instead of crisp values, dealing with qualitative linguistic

terms which are computed by a fuzzy algorithm is more advantageous.

An example system is presented in this paper which has shown its adoptability. This is just a start, there are several improvements could be made in the future if more data are attainable:

- More fuzzy linguistic variables could be included into the model.
- When define the fuzzy membership function, some AI method could be used to make the membership function more sensible.
- With more data, more fuzzy rules could be constructed.

With a larger and better intelligent database system established in the future, more accurate and reliable results can be achieved, which will be helpful for the practitioners to better understand and predict their companies' competitiveness in the industry more effectively and efficiently.

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