Research on Fuzzy Comprehensive Evaluation Model of Ship type Main Dimension

Hongbin Wei*
1China waterborne transport research institute, shipping technology research centre, Beijing, 100088, China
*Corresponding author’s e-mail: whb@wti.ac.cn

Abstract. In order to formulate the main dimensions of standard ship form systematically and reasonably, this paper first systematically comb the development status of the main dimensions of standard ship form at home and abroad. For foreign countries, from the perspective of waterway standards and the development time of inland river standard ship form construction, this paper discusses the development process of ship form standardization in the United States and the European Union; for domestic countries, from the perspective of the relevant management documents of waterway and inland river navigation ships that have been issued, the development process of ship form standardization in China is discussed. Secondly, a fuzzy comprehensive evaluation model is established by using the theory of fuzzy mathematics and the comprehensive evaluation method. This paper discusses the selection of evaluation indexes in the evaluation method by using the benefit analysis of participants, analyses the composition of the existing standardization index system of ship form, and delimits the factors for the selection of evaluation indexes. Finally, the formulation principle and composition of the evaluation index system are given.

1. Introduction
Developed countries attach great importance to the standard and construction of the main dimensions of ship types in key inland river systems. Especially attention is paid to the mode of fleet transportation. Taking the United States and the European Union as an example, the choice of inland waterways and modes of transport corresponds to the maximum capacity of a single vessel and the maximum capacity of a fleet. From the development of capacity scale, it can be seen that fleet transportation mode is obviously superior to self-propelled single vessel. The selection of transportation mode should be based on the factors such as channel size, lock size, flow conditions and volume of transportation.

Table 1. Form standardization management of ship forms in developed countries

| Zone        | Water transport | River system            | Self-propelled Ship Transportation (Ship Tonnage: Tonnage) | Fleet Transportation (Fleet Tonnage: 10,000 Tonnage) |
|-------------|-----------------|-------------------------|----------------------------------------------------------|------------------------------------------------------|
| American    | Mississippi River System | 2000                  | 8                                                       |                                                      |
| European    | Rhine River System    | 1500                  | 1                                                       |                                                      |

In order to limit the external negative effects of ships and speed up the modernization of ships, the Ministry of Transport and the Ministry of Finance jointly launched a series of demonstration projects of ship standardization since 2001. In 2001, the former Ministry of Communications promulgated the
Regulations on Standardized Management of Inland Waterway Transport Vessels. In 2003, the demonstration project was carried out on the Beijing-Hangzhou Canal. In 2009, the standardization of ship types was fully promoted on the Yangtze River trunk line and in 2013.

Table 2. China ship forms standardization management

| Zone                                      | Water transport                                                                                   | Job content                                                                                           |
|-------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| China                                     | "Regulations on Standardized Management of Inland Waterway Ships","National Outline for the Standardization of Inland River Ship Forms","Principal Size Series of Standard Ship Types for Transport Vessels on the Beijing-Hangzhou Canal","Principal Size Series of Standard Ship Types for Shipping in Chuanjiang and Three Gorges Reservoir Area","Principal Scale Series of Freight Ships on the Pearl River Trunk Line" | The submission and examination of 14 series and 25 kinds of standard ship form drawings of the Beijing-Hangzhou Canal have been carried out. The technical scheme for the development of 8 kinds and 42 kinds of standard ship form in Chuanjiang River and Three Gorges Reservoir Area has been put forward. |

2. Fuzzy comprehensive evaluation model

Fuzzy evaluation model is based on the theory of fuzzy mathematics, using comprehensive evaluation method and analytic hierarchy process, under the condition of basic parameters, through this model, we can get the method to measure the merits and demerits of the main dimensions of multi-scheme ships.

2.1. Fuzzy Mathematics Theory

Looking at the world from the perspective of mathematics, phenomena can be divided into deterministic phenomena, random phenomena and vague phenomena. The basic idea of the fuzzy theory is to substitute the degree of belonging for the degree of belonging or not belonging. The basic concepts used in fuzzy mathematics are fuzzy set and membership degree. The deterministic phenomena correspond to classical sets, which represent all objects with certain deterministic attributes and can be distinguished from each other. The corresponding set language is a characteristic function, which is used to judge whether an object belongs to the whole or not. The corresponding operation is set operation. Fuzzy phenomena correspond to fuzzy sets, which represent the whole of objects described by some kind of fuzzy attributes. The corresponding set language is a membership function, that is, a function used to judge whether an object belongs to the degree of fuzzy totality.

Given a universe $U$, then a mapping from $U$ to unit interval $[0,1]$

$$\mu_A : U \rightarrow [0,1]$$

It is called a fuzzy set on $U$, or a fuzzy subset of $U$.

For general set $A$, it can be understood as a subset of a domain $U$. In order to describe whether any element $u$ in universe $U$ belongs to set $A$, it is usually marked by 0 or 1.

A binary function $A(u)$ on $U$ is obtained by using 0 to denote that $u$ does not belong to $A$ and 1 to denote that $u$ belongs to $A$. It characterizes the subordination of $U$ to ordinary sets. It is usually called the Eigen function of $A$. In order to describe the subordination of element $u$ to a fuzzy set on $U$, because of the ambiguity of this relationship, it will replace the values of 0 and 1 with the values of subordinate interval $[0,1]$. Description, denoted as $(u)$. Number $(u)$ denotes the degree to which the element belongs to the fuzzy set. Function $u$ on universe $U$ is the membership function of the fuzzy set, and $\mu(u)$ is the membership degree of $u$ to $A$. 
2.2. Fuzzy Comprehensive Evaluation

Comprehensive evaluation method is a systematic and scientific evaluation method, which considers all the indicators comprehensively and assigns a certain weight to each index. By multiplying the score and weight of each index, we can get the overall evaluation of things or schemes. The concrete operation steps of the fuzzy comprehensive evaluation method are to determine the factor set of the fuzzy comprehensive evaluation firstly, and the factor set is the set of evaluation indexes; the second step is to determine the comment set, which is the set of optional values of each evaluation index; the third step is to determine the weight of each factor, that is, to score the importance of the evaluation index; the fourth step is to establish the evaluation matrix, and to subordinate each factor of things to each comment. The degree of evaluation (judges ’score or membership function) determines the fuzzy comprehensive evaluation matrix and evaluates each factor. The fifth step of the fuzzy comprehensive evaluation is to calculate the total evaluation based on the appropriate fuzzy synthesis operator, and then make the judgment according to the principle of maximum membership degree.

3. The selective method of evaluation index

3.1. Analysis of Participants ‘Interests’

Ship form evaluation criteria are the core part of ship form evaluation. Typical evaluation criteria are related to the expected benefits or the costs that project participants have to pay. Therefore, evaluation criteria vary from person to person.

- In order to improve the competitiveness of ship-owners, it is necessary to reduce shipping costs, improve profit margins and shorten the payback period of investment.

- Shipping management departments will pay more attention to the efficiency of large logistics corridors and energy saving, environmental protection and safety of ships.

- For the ships passing through the Three Gorges Lock, the lock management department is most concerned about the adaptability of the ship's main dimensions to the Three Gorges Lock, that is, whether many ships can make full use of the lock chamber space to enhance the capacity of the Three Gorges Lock (due to the restrictions of the Yangtze River channel conditions and port facilities, the single ship cannot make full use of the lock chamber space).

Therefore, for a certain type of ship, its advantages and disadvantages vary with the inspectors. It is necessary to establish comprehensive evaluation criteria to synthesize the opinions of all parties in order to form a scientific and objective conclusion.

Therefore, it is necessary to adopt comprehensive evaluation method to comprehensively evaluate the main dimensions of ship form, establish comprehensive evaluation criteria and take into account the opinions of all parties.

3.2. Existing Indicator System

Compared with the previous documents, the existing standardization management documents expand the technical requirements of standard ship form from "main scale series" to "index system". Standardization indicators are no longer only the main scale series of ship form, but also include mandatory indicators of energy saving and emission reduction. At the same time, advanced recommended indicators are added.

| Serial number | Focus     | Index type         | Index requirements                                                                 |
|---------------|-----------|--------------------|------------------------------------------------------------------------------------|
| 1             | Security  | Mandatory indicators | Meet safety requirements and ship building codes and regulations.                  |
|               | High      | Mandatory indicators | It meets the requirements of energy saving, meets the energy consumption targets, and improves the energy efficiency performance of |

Table 3. The focus of establishing the existing index system
4. Composition of index system

4.1. Principles for Establishing Evaluation Index System

On the premise of meeting the transportation demand and ensuring the safety of ships, the main objective is to improve the capacity of locks.

The adaptability of shipping infrastructure (channel, wharf, bridge, lock, etc.), social benefit (EEDI), technical performance (ship safety, ship speed, manoeuvrability, etc.), economic performance (ship loading capacity, cost index, benefit index, etc.) should be considered comprehensively.

By using qualitative and quantitative analysis, theory combined with practice and multi-disciplinary integration, a comprehensive evaluation model is constructed to objectively evaluate the comprehensive benefits of ship type, effectively alleviate the contradiction between the demand for locks and the inadequate capacity of locks, and maximize the economic benefits of transportation.

4.2. Composition of evaluation index system

The evaluation index system is composed of four kinds of indicators: lock adaptability index, navigation safety index, technical and economic index of ship passing through lock and energy saving and environmental protection index of ship.

Lock adaptability index: In order to improve the throughput of the Three Gorges Lock, the adaptability index of the lock reflects the efficiency of each selected ship combination, i.e. the area utilization ratio of lock chamber A and the tonnage of lock in unit time B. The bigger the two indexes, the better.

Navigation safety index: Navigation safety mainly includes the safety of lock facilities and the safety of ships themselves. Navigation Safety Index of Ship Locks: C Floating Mooring Pillar berthing capacity as an evaluation index

D-manoeuvrability analysis of the new main-scale ship type - high initial stability, to evaluate the safety of the ship's navigation.

Technical and economic indicators: Navy coefficient AC and cargo capacity coefficient ZZXS are selected as technical indicators. The bigger the EF value of these two indexes is, the better it will be. Technical index of ship form Necessary Freight RFR, DYQD of Unit Fuel Consumption and Transportation Efficiency YSXL as Criteria-Economic Index of Ship Type.

Energy saving and emission reduction targets: The ship energy efficiency design index EEDI is a measurement tool to characterize the inherent CO2 emission level of ships in the design and construction stages.

5. Concluding

In this paper, the development status of ship form and scale at home and abroad is discussed, the fuzzy evaluation model is constructed, the principle of establishing evaluation index system is elaborated, and the evaluation index system is constructed. Based on the theory of fuzzy mathematics and the comprehensive evaluation method, the operation steps of the fuzzy comprehensive evaluation method are put forward. For the selection of indicators in the fuzzy comprehensive evaluation method, from the
perspective of ship-owners, shipping management departments and lock management departments, multi-dimensional analysis of the stakeholders of evaluation indicators is carried out. It is pointed out that the establishment of the index system should start from four aspects: safety, efficiency, green and advanced. For the composition of the index system of fuzzy comprehensive evaluation, this paper puts forward the principle of formulating the evaluation index with the main objective of improving the capacity of locks on the premise of meeting the transportation demand and transportation safety. The evaluation index system is composed of four kinds of indexes: lock adaptability index, navigation safety index, technical and economic index of ship passing through lock and energy saving and environmental protection index of ship.

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