Evaluation of pilotage dispatching operation for Dalian Port in China based on FCE–AHP method

Jing Du, Yu Jiang, Kun Wang, Guangjun Song, Jing Wu, Lun Song, Jinhao Wu, Jin Tian and Zhiqiang Ma

ABSTRACT
Objective: The continuous expansion of the port with the critical shortage for maritime pilots and vessels calls for an effective pilotage dispatching operation, which can ensure the timely delivery of information and rational utilization of pilotage resources. How to evaluate the effectiveness of the pilotage dispatching operation for a port has been studied little internationally. Thus, a hybrid model of fuzzy comprehensive evaluation (FCE) and analytic hierarchy process (AHP) is set up in this paper for effectiveness evaluation of the port pilotage dispatching operation. Method: A comprehensive evaluation index system is designed by AHP method while FCE method based on anti–fuzzy method is formulated for assessing the effectiveness of pilotage dispatching operation. Moreover, pilotage dispatching system assessment of Dalian Port in China is presented as a case. Results: FCE–AHP method is suitable for effectiveness evaluation of pilotage dispatching system, and the pilotage dispatching system of Dalian Port is better than “general” and close to “good” obtained by anti–fuzzy method. Conclusion: FCE–AHP method is validated its feasibility for effectiveness evaluation of the port pilotage dispatching operation and more related parameters will be considered in the further study.

Introduction
Maritime pilotage refers to the pilotage institutions or branches qualified by the competent authority that send pilots to the ships and guide ships on arrival and departure to and from the port (Zhang et al. 2013). Pilotage service cannot only guarantee the ship’s security when it is entering and exiting the port and protection of the marine environment from ship-sourced pollution, but also has a great significance in enhancing the institution’s service image. As the most complex and critical operation in the maritime domain, pilotage serves as a joint cognitive system by exchanging the information among all links continuously. With the development of the domestic and international shipping market and an increase in ship tonnage and number, pilotage for every global port meets great challenges and attracts more and more academic concerns. A number of studies have been reported with regard to the pilotage technologies, such as an electronic pilotage tool of new generation proposed by Phinney (1998) improving the efficiency and safety of pilotage services significantly. Previous researches have also dealt with pilotage management systems aligned with advanced technologies, such as remote sensing and control systems, etc., which were designed for accurate and timely information supply (Smith and Casper 1991; Aldridge and Smeaton 1997) and they have been applied to the port, gulf, and inland management systems (Venkatesh and Wanagas 1995). Moreover, based on Formal Safety Assessment (FSA) method, Zaman et al. (2015) advanced quantitative retrospective analysis of maritime operations and proposed some suggestions for improvement through the analysis of the influencing factors. These researches demonstrate that pilotage has become a research hotspot in recent years.

Pilotage dispatching operation can be regarded as a comprehensive stage involving the collection and processing of multiple types of data with changeable information, complicated factors and large determined scopes during pilotage service process (Li 2011). These variables remarkably increase the complexity and difficulty of the pilotage dispatching operation. An effective pilotage dispatching operation is a formidable task of pilotage service, which means timely communication with stakeholders, scientific, and reasonable pilots dispatching and full vessels utilization synchronously. Thus, pilotage dispatching operation, especially its effectiveness evaluation is yet to be explored. However, the effectiveness evaluation for the pilotage dispatching operation has been rarely done (Ren, Pan, and Liu 2011) and research suggests the lack of the computerized models for pilotage dispatching operation evaluation up
to now (Yang and Wang 2011). It is obvious that parameters for the effectiveness evaluation of pilotage dispatching operation cannot be accurately accounted for as the exact numerical values for the criteria are difficult to be quantitatively expressed. Thus, it can be inferred that some quantitative computerized models are not suitable for the effectiveness evaluation of pilotage dispatching operation.

Then, it is necessary to propose an integrated method which is able to handle these multiple factors and fuzziness combined with quantitative analysis for pilotage dispatching operation effectiveness evaluation. Fuzzy comprehensive evaluation (FCE) which quantifies the fuzzy indexes of evaluation objects through establishing grade fuzzy subset and utilizing a fuzzy variable principle to integrate each index (Du et al. 2011) is expected to better solve this fuzzy problem. Meanwhile, analytic hierarchy process (AHP), developed by Thomas L. Saaty in the 1970s (Saaty 1980), has proved to be a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology (Saracoglu 2013). This method, which has been extensively studied and refined since it was proposed, has been used in almost all the applications related with decision-making (Saaty and Peniwati 2008). It is undoubtedly a multiple criteria decision-making tool that can overcome the drawback of criteria being unable to quantify (Vaidya and Kumar 2006). The combination method of FCE and AHP has gotten better evaluation effects in some recent researches related to port logistics. Ma (2007) used the FCE–AHP method to establish a port logistics competitiveness evaluation model and conducted a comparison on the competitiveness of the ports between Shanghai and Fushan. Besides, Liu, Jiao, and Ma (2008) appraised comprehensive performance of Ningbo–Zhoushan port logistics by FCE–AHP method, and put forward some suggestions for upgrading its competitiveness according to the evaluation results.

In this study, to overcome the complexity of structure and the uncertainty of various parameters, a combined FCE–AHP method is proposed for effectiveness evaluation of port pilotage dispatching performance. Firstly, FCE–AHP model is briefly described. Then, based on an explicit introduction of Dalian Port’s maritime pilotage service, a comprehensive evaluation index system is designed by AHP method while FCE method is formulated for assessing the effectiveness of its pilotage dispatching operation. After discussion for the evaluation results, some suggestions are put forward to make the port take pertinent measures which can contribute to upgrading its pilotage service.

**FCE–AHP model description**

A comprehensive FCE–AHP model can be summarized into three stages: (1) Evaluation criteria determination; (2) FCE–AHP model establishment and calculation; (3) Ranking results evaluation.

**Evaluation criteria determination**

First, set up the level hierarchical model including goal, criteria, and sub-criteria, in which the different indicators are identified by the expert group with a comprehensive understanding in related field along with some filed investigation and other related research results.

**FCE–AHP model establishment and calculation**

FCE model involves five factors: (1) Factor set $U$; (2) weight distribution vector $W$; (3) Comment set $V$; (4) Evaluation matrix of factor $R$ and (5) FCE result $B$.

The concrete model is constructed as follows:

1. Establish a finite set $U$

   Break down the problem into a hierarchy of decision elements in order to develop a decision hierarchy. Let $U = \{U_1, U_2, \ldots, U_m\}$ be the factor set to evaluate different schemes. $U_i$ stands for the aggregate composed of criteria hierarchy. Each factor $U$ includes secondary factor set $U_j = \{u_{ij}, u_{ij}, \ldots, u_{nj}\}, j = 1, 2, \ldots, n; i = 1, 2, \ldots, m$; $u_{ij}$ stands for the sub-criterion $j$ of the criterion $i$.

2. Calculate the weight set $W$

   The weight, that is, the extent of recognition of factors from evaluators can be viewed as the fuzzy subset of factor full set $U$ when an object is evaluated roundly with the weight set $W$. $w_i$ stands for the weight for $U_i$.

   \[
   W = \{W_1, W_2, \ldots, W_m\}, \quad \sum_{i=1}^{m} W_i = 1 (i = 1, 2, \ldots, m), \quad W_i \geq 0 (i = 1, 2, \ldots, m)
   \]

3. Calculate the comment set $V$

   The concrete model is constructed as follows:

   \[
   V = \{v_1, v_2, \ldots, v_n\}, \quad \sum_{j=1}^{n} v_j = 1 (j = 1, 2, \ldots, n), \quad v_j \geq 0 (j = 1, 2, \ldots, n)
   \]

   Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another at a time, with respect to their impact on their higher hierarchy. First, produce judgment data by pairwise comparison matrix of the decision elements. A nine-point (1–9) numerical scale of AHP is used. The numerical scale used for assigning values to these comparative ratings is shown in Table 1.

   Second, calculate the weight set for each factor by geometric mean method (root method). That is, calculate the product \((M)\) of each judgment data in each line \(M_i = \prod_{j=1}^{n} U_{ij}, i = 1, 2, \ldots, m\). And then, calculate \(W_i^\prime\) as \(m\) th root of \(M_i\)

   \[
   W_i = \left( \frac{M_i}{\prod_{j=1}^{n} W_j} \right)^{1/m} (i = 1, 2, \ldots, m), \quad j = 1, 2, \ldots, n
   \]

   As it is the essence of AHP that human judgments, and not just underlying information, can be used in performing the evaluations, the consistency of the judgment
matrix must be checked to ensure that the calculated weights are acceptable. The consistency ratio can be determined by $CR = \frac{max\{\lambda_i\} - n}{n-1}$. $RI$ is the random index, which can be look up in Table 2 (Nie, Dai, and Yue 2013), and $\lambda_{max} = \sum_{j=1}^{m} \left( \frac{CW}{WT} \right)$. When the consistency ratio is less than 0.1 $(CR < 0.1)$, we think the inconsistent degree of $W$ is within the allowable range.

(3) Comment set $V$

For a certain scheme, according to the factor set $U$, suppose it receives a comment set $V = \{v_1, v_2, \ldots, v_p\}$ ($v_i$ stands for the comment of fuzzy language evaluation for factor $u_i$).

As comment sets given by experts are all difficult to be quantified and fuzzy, such an uncertain and imprecise issue can be evaluated by expert scoring method and the percentage of grade $v_i$ rating in the index $i$ is taken as fuzzy membership index.

(4) Evaluation matrix $R_i$

The fuzzy relation between factor full sets and remark full sets can be described by the evaluation matrix $R$:

$$R_i = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

with $r_{ij}$ representing the grade of membership of factor $u_i$ aiming at the comment $v_j$, $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n; k = 1, 2, \ldots, p$.

(5) FCE $B$

Let $B$ as synthesized by $A$ and $R$ be the final evaluation of an object with many factors considered by the valuator, which mathematical model is:

$$B = W \cdot B_i = \{b_1, b_2, \ldots, b_p\}.$$  

### Table 1. Relative importance judge demarcate of AHP.

| Comparative judgment          | Scale of the relative importance |
|--------------------------------|----------------------------------|
| The two factors have an equivalence importance | 1                               |
| One factor is moderately more important than the other | 3                               |
| One factor is obviously more important than the other | 5                               |
| One factor is much more important than the other | 7                               |
| One factor is extremely more important than the other | 9                               |
| Intermediate values between two adjacent judgments | 2, 4, 6, 8                      |

### Table 2. RI value for the average stochastic consistency evaluation.

| $n$ | 1   | 2   | 3   | 4   | 5   | 6   |
|-----|-----|-----|-----|-----|-----|-----|
| RI  | 0   | 0   | 0.58| 0.90| 1.12| 1.24|

### Ranking results evaluation

Usually, ranking results evaluation can be dealt with the maximum membership principle or anti-fuzzy method. The calculated rations of the maximum membership principle are displayed as follows: $b_1$ (proportion of comment 1), $b_2$ (proportion of comment 2) $\ldots b_p$ (proportion of comment $p$). Then, the final evaluation result should be $B' = max(B)$. The anti-fuzzy method uses the weighted average of every evaluation vector as the final results, corresponding to different orders of evaluation. That is, $V = \frac{\sum_i b_i}{\sum_i b_i}$. Then, the calculated $V$ is compared with the comment set to finish the ranking results evaluation.

### Effectiveness evaluation of pilotage dispatching operation by FCE–AHP method for Dalian Port

**Maritime pilotage service of Dalian Port**

Located at the entrance of Bohai Bay of China, Dalian Port acts as a strategic and conveniently positioned port for shipping companies since it operates throughout the year with deep water and ice-free port conditions. Presently, there are more than 120 terminal berths for containers, oil/liquefied chemicals, automobiles, ores, bulk grains, RO-roll as well as general cargos, in which the number of 10,000 ton-level berths are over 50. The pilotage service of Dalian Port has experienced rapid development with the improvement of the port, which is most evidently exemplified in the workload of the pilotage operation. In 1951, only 1587 ships were piloted in Dalian for the whole year, but in 2002 the figure jumped to 11,526, in 2003 to 12,460, in 2005 to 13,498 ships, and in 2009 the port handled 17,590 ships, which was the highest recorded in the history of Dalian Port. At the same time, the port’s cargo throughput from Dalian Port has also increased significantly and it was reported to have reached 3550 million tons in 2016 (Figure 1).

According to the international practices and the government regulations of China, to enter and exit China’s ports, foreign ships should apply for piloting through the pilot organizations. This is not only required because of the Nation’s sovereign safeguard over its territorial waters and the National Defense Security, but it’s also an essential means to guarantee the safety and punctuality of the ships’ entrance and exit from the port and also to maintain the public security of the port. Dalian maritime pilot station, affiliated with the Port of Dalian Authority (PDA, now named the Dalian Port Company Limited), is the only professional institution providing the pilotage service to all vessels entering or departing from Dalian Port on a 24 h basis, 365 days of the year in all weather conditions and port circumstances. However, so far, the Dalian maritime pilot station comprising of its 6
departments and 74 workers, only has 58 maritime pilots. Thus, the pilotage dispatching work has become more and more challenging due to the expansion of the port’s area with a greater increase in the port’s throughput and a need of more maritime pilots and pilot launches.

For the pilotage service of Dalian Port, all the departments including the shipping agency, Tug & Barge Corporation, ships, PDA, Pilotage Dispatching Station and maritime pilots need to coordinate and cooperate with each other. Detailed pilotage service operations of the Dalian port are expressed in Figure 2. Firstly, the clients or their agents shall report to the pilotage dispatching station with the next 24 h action plans of the ships via the internet, fax, telephone, or other means before 10 AM in the morning. Secondly, the clients or their agents then send additional applicable information to the pilotage dispatching station, which contains information about the shipping companies, ships’ name (in Chinese and English), nationalities, call sign of the vessels, ship type, total length, width, draft, height above the water, gross tonnage, net tons, deadweight tonnage, host, type and power of lateral thruster, ships’ speed, time and position of arrival and departure, the port of departure and destination, the way of settling accounts of pilotage

![Figure 1](image1.png)

**Figure 1.** The pilotage development of Dalian port since 1951.

![Figure 2](image2.png)

**Figure 2.** Flow chart of the pilotage dispatching system of Dalian Port.
expenses, and other relevant matters. Thirdly, according to the ships’ pilotage application, the meteorology and hydrology conditions, the pilotage dispatching station can make a plan for the pilotage service action and submit it to the Vessel Traffic Service (VTS) before 11 AM. Lastly, the pilotage dispatching station informs the clients or their agents of the pilotage service time and other relevant information, which also guides and assists pilots in completing the work in a timely matter.

**Effectiveness evaluation of pilotage dispatching operation by FCE–AHP method**

*Establishment of the level hierarchical model*
Along with the complicated cooperation relationships, the high manufacturing consistency and the frequency of unexpected weather conditions during the pilotage service, the indispensable pilotage dispatching operation has always been considered as the brain and center of the port’s piloting process. Researchers believe that interfaces the pilotage equipment have and the communication links between Captain, Pilot, Duty officer, and other stakeholders, influence how the pilotage dispatching operation effectively works (Sharma and Nazir 2017). Thus, in this study, effectiveness evaluation system is classified into three subsystems, including ship situation, interference factors, and possible surrounding environment options. Ship situation, such as ship numbers in port, ship tonnage (length) and ship host status contribute to the dispatching time. Interference factors refer to the professional abilities of the pilots, crew and dispatchers, reporting and monitoring system as pilotage dispatching operation unequivocally requires team work among all stakeholders, as well as laws and regulations because they are the policy guarantees for the pilotage dispatching operation. Possible surrounding environment options including hydrological condition, meteorological condition, waterway condition, and terminal condition provide basic information of the port which closely related to actual pilotage operation. Therefore, there are totally 12 factors included in the three subsystems.

Accordingly, a three-layer hierarchical model is established to evaluate the effectiveness of pilotage dispatching operation for port management reasonably. The goal layer is effectiveness evaluation of pilotage dispatching operation. The criteria layer includes the above three subsystems while the sub-criteria layer is consist of 12 factors. The level hierarchical model of effectiveness evaluation is shown in Figure 3.

**FCE–AHP model application**

1. Establish a finite set
   In this study, a finite set $U$ is divided into two levels, being criteria hierarchy and sub-criteria.
   The criteria hierarchy is described as $U = \{U_1, U_2, U_3\}$. $U_i$ stands for the aggregate composed of criteria hierarchy, $i = 1, 2, 3$. According to the Level Hierarchical Model, $U_1$ is ship situation, $U_2$ is interference factor and $U_3$ refers to possible surrounding environment options. Each criterion $U_i$ includes secondary factor set $U_i = \{u_{i1}, u_{i2}, \ldots, u_{in}\}, j = 1, 2, \ldots, 6$. $u_{ij}$ stands for the sub-criterion $j$ of the criterion $i$.

2. Calculate the criteria weights
   The judgment matrix is determined by expert decision along with field investigation and other related research results. Take $W$ as an example, which is described in Table 3 in detail:
   \[
   W = \begin{bmatrix}
   1 & 1/2 & 2 \\
   2 & 1 & 3 \\
   1/2 & 1/3 & 1
   \end{bmatrix}
   \]
   (1) Set judgment data, $W = \begin{bmatrix}
   1 & 1/2 & 2 \\
   2 & 1 & 3 \\
   1/2 & 1/3 & 1
   \end{bmatrix}$;
   (2) Calculate the product $(M_i)$, $M_1 = 1, M_2 = 6, M_3 = 1/6$;
   (3) Calculate $W'_i$, $W'_1 = 1.8171, W'_2 = 0.5503$;
   (4) Do normalization processing $W_i$, $W_1 = 0.2970, W_2 = 0.5396, W_3 = 0.1634$;
   (5) Calculate consistency ratio, $CR = 0.0083 < 0.1$ ($\lambda_{max} = 3.0096, RI = 0.58$)

![Figure 3](image-url). Fuzzy AHP hierarchy for pilotage dispatching operation of Dalian port.
The evaluation matrix of other factors can be acquired in the same way, and the calculation results of all the criteria weights are presented in Tables 4–6.

(3) Compose comment set
Comment set is composed of the judgment results of the evaluation object. This study adopts a five-grade comment system, and that is:

\[ V = \{ v_1, v_2, v_3, v_4, v_5 \} = \{ \text{very good, good, general, poor, very poor} \} = \{ 5, 4, 3, 2, 1 \} \]

The comment sets for each criterion of effectiveness evaluation are summarized in Table 7. It is determined by referencing the decision opinions by expert combined with engineering practice.

(4) Make evaluation matrix
In this study, expert scoring method is used for comments on each criterion and the percentage statistic is expressed for the grade of membership index. The evaluation results of membership grade of all factors are described in Table 8. Reference the Membership functions of the number of ships \( u_{1,1} \), ship tonnage (length) \( u_{1,2} \), and condition of ship’s host \( u_{1,3} \), we constitute an evaluating matrix \( R_1 \) and then get a comprehensive evaluation vector by calculating with the weight.

\[ R_1 = W_1 \cdot \begin{pmatrix} 0.2 & 0.3 & 0.3 & 0.1 & 0.1 \\ 0.3 & 0.4 & 0.2 & 0.1 & 0.0 \\ 0.5 & 0.2 & 0.2 & 0.1 & 0.0 \end{pmatrix} = (0.3030, 0.3376, 0.2297, 0.1000, 0.0297) \]

Table 7. Comment sets for each criterion of effectiveness evaluation.

| Criterion                          | Comment sets                  |
|------------------------------------|-------------------------------|
|                                    | Very good | Good | General | Poor | Very poor |
| Ship numbers                       |           |      |         |      |           |
| Ship tonnage (length)              | More suitable for port capacity | Suitable for port capacity | Generally suitable for port capacity | Less suitable for port capacity | Unsuitable for port capacity |
| Ship host condition                | More suitable for port terminal | Suitable for port terminal | Generally suitable for port terminal | Less suitable for port terminal | Unsuitable for port terminal |
| Pilots professional ability        | Excellent | Good | General | Poor | Very poor |
| Very high                          | Good      | General | Low     | Very poor |
| Very high                          | High      | General | Low     | Very low |
| Very high                          | High      | General | Low     | Very low |
| Reporting system                   | Perfect   | Very high | General | Poor | Very poor |
| Monitoring system                  | Very high | High | General | Low execution efficiency | No execution |
| Monitoring system                  | High execution efficiency | Perfect | Good | General | Low flow rate, high wave, large tidal range |
| Hydrological condition             | Low flow rate, low wave, small tidal range | Low flow rate, low wave, large tidal range | Low flow rate, high wave, large tidal range | High flow rate, low wave, large tidal range | Typhoon, no fog, strong wind |
| Meteorological condition           | No typhoon, no fog, no strong wind | No typhoon, fog, no strong wind | No typhoon, fog, strong wind | Typhoon, no fog, strong wind | Typhoon, fog, strong wind |
| Waterway condition                 | The number of intersection < 2 | The number of intersection < 4 | The number of intersection < 6 | The number of intersection < 8 | The number of intersection > 8 |
| Terminal condition                 | Good for berthing | Good for berthing | General for berthing | Poor for berthing | Very poor for berthing |

\[ R_1 = (0.2970, 0.5396, 0.1634) \cdot \begin{pmatrix} 0.3030 & 0.3376 & 0.2297 & 0.1000 & 0.0297 \end{pmatrix} \]
The fuzzy evaluation for other factors of the pilotage dispatching work, that is B2 and B3 can be acquired in the same way:

\[
B_2 = W_2 \cdot R_2 = (0.3848, 0.3038, 0.1853, 0.0962, 0.0361)
\]

\[
B_3 = W_3 \cdot R_3 = (0.2378, 0.3098, 0.2070, 0.1745, 0.0718)
\]

(5) Fuzzy evaluation

Evaluation vectors are received in the first level to constitute evaluating matrix \(B_i\), and then calculated with the weight of the \(U_i\), \(U_j\), and \(U_k\) to get a comprehensive evaluation vector \(\hat{B}\).

\[
\hat{B} = W \cdot B_i = (0.2970, 0.5396, 0.1634) \cdot \begin{bmatrix} 0.3030 & 0.3376 & 0.2297 & 0.1000 & 0.0297 \\ 0.3848 & 0.3038 & 0.1853 & 0.0962 & 0.0361 \\ 0.2378 & 0.3089 & 0.2070 & 0.1745 & 0.0718 \end{bmatrix} = (0.3365, 0.3147, 0.2020, 0.1101, 0.0401).
\]

**Ranking results evaluation**

In order to avoid the disadvantage of information loss in the maximum membership principle, the anti-fuzzy method is used for ranking results evaluation in this study. According to the anti-fuzzy method, the result of the weighted average is as follows:

\[
V = \frac{\sum_i \hat{B}_i \cdot v_i}{\sum_i \hat{B}_i} = \frac{0.3365 \cdot 5 + 0.3147 \cdot 4 + 0.2020 \cdot 3 + 0.1101 \cdot 2 + 0.0401 \cdot 1}{0.3365 + 0.3147 + 0.2020 + 0.1101 + 0.0401} = 3.7947.
\]

Thus, according to the above comment set, this result indicates that the pilotage dispatching work at the Dalian Port is better than “general” (\(V = 3\)) and close to “good” (\(V = 4\)).

**Discussion**

The main difficulties in effectiveness evaluation of pilotage dispatching operation are the complexity of mechanism and the uncertainty of variable, so the research about this item is very rare. As a response to this dilemma, the combinational method of FCE and AHP has been proposed to solve the complex and uncertain problems in the area of maritime pilotage service for port management. And a case study for the pilotage dispatching system assessment of Dalian Port in China is presented to validate the feasibility of the approach. The results show that FCE–AHP method is suitable for effectiveness evaluation of pilotage dispatching system, and that of Dalian Port is better than ‘general’ and close to “good” obtained by anti-fuzzy method.

Firstly, the complex structure of pilotage dispatching operation system is taken into consideration, because of the complexity of dispatching operations including communication with agents and terminals by various means to learn about the ships’ entering and leaving, and huge sums of information providing in the shortest possible time. There are many external factors affecting maritime pilotage service, especially pilotage dispatching operation. To deal with this challenge, based on the analysis of evaluation structure, 12 criteria have been divided into three groups in accordance with the subsystems to determine the contribution degree for total effectiveness. However, the model in this study is simplified to assess only a few aspects of pilotage dispatching operation effectiveness for a port. Environmental aspects are not assessed at all, and there is a need for more parameters to assess safety of pilotage process.

Besides, the hierarchy relationships of effectiveness evaluation factors have been built clearly by AHP method, while the selection of judgment matrix is completed by experts’ engineering practice experience with percentage statistic expression. Certainly, AHP still suffers from some theoretical disputes, such as the assumption of criteria independence and in fact exact numbers are inappropriate for linguistic judgments in this study. Hence, more related parameters, as well as fuzzy number for membership function, such as triangular fuzzy number, trapezoidal fuzzy number may be considered in the next research.

Thirdly, in recent years, Dalian Port spans over a larger area than before and it has established some sub-pilot stations. But it just maintains one command center for optimizing pilotage command and service in order to fully grasp the dynamics of ships and make scientific and reasonable allocations. Then, although the results show that the pilotage dispatching operation of Dalian Port is nearly good, there are still some measures to be taken which can upgrade its competitiveness. Such as, advanced pilotage equipment should be utilized to provide assistance for pilots in a timely and accurate
manner which can contribute to the factor of pilots professional ability. Formulating specific pilotage dispatching plans for some important ships in the foggy season or unfavorable weather can increase the factor scores of dispatchers professional ability and meteorological condition. Moreover, the pilot transportation processes can be optimized which is beneficial to energy conservation and waste emission reduction in despite environmental factors not considered in this study.

**Conclusion**

In this study, we have proposed an effectiveness evaluation method, a combinational method of FCE and AHP, which provides a quantitative evaluation for pilotage dispatching operation of port management. The very comprehensive identification of influence factors has been done by analyzing the structure of pilotage dispatching operations. The weight of each layer is calculated by AHP method and the results of effectiveness level for pilotage dispatching unit are obtained by FCE method based on anti-fuzzy method. The case study for Dalian Port, China validates the feasibility of this approach. We believe the model presented in this paper may be a stepping stone into larger research efforts.

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