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Identification of Water Traffic Black Spot

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Abstract

Through defining Water Traffic Black Spot and analyzing the advantages and disadvantages of identification methods of Road Traffic Black Spot, then choosing Quality Control Method to recognize water area of intensive traffic accidents and applying integrated influential intensity of accident rate based on Systematical Clustering Algorithm into defining the boundary of the area, an effective evaluation method of black spot identification that is established, which lays a foundation for the subsequent evaluation work.

Introduction

The distribution of water traffic accidents is both timeliness and spatiality. The spatiality of accidents could be divided into dispersing type and intensive type. In the study of road traffic accidents, the area of intensive accidents is always called "Black Spot". Domestic and overseas scholars have studied road traffic black spot from numerous aspects; however studying about water traffic black spot is deficient. Identification and preferential renovation sequence of water traffic black spots have a significant meaning to reduce water traffic accidents and improve the safety management of water traffic.

Definition of Water Traffic Black Spot

Ships will be affected by many factors when voyaging in the costal or inland, such as seamen, ship conditions, and environment etc. These factors work together caused the water traffic accidents which occur in a certain waters intensively, and then the intensive water area is called "Water Traffic Black Spot".

There is no related definition about water traffic black spot. The definition of water black spot in this paper is as follow: in a period of time, water traffic accidents occur in a water area intensively, the water area can be described quantitatively (length, width, diameter or area etc.), and the quantity and attribute of accidents and the risk feature of the water area is significantly different from other water areas.

Identification Methods Reviews

There are numerous studies about the identification of black spot in the field of road traffic. There are some similarities between road traffic and water traffic, so the identification of water traffic black spot can reference the research thoughts, methods and models of road traffic, then combining the reality of water traffic to establish the water traffic black spot identification model. The existing identification model of road traffic black spot can be divided into two parts, one is methods based on data statistics, such as accident frequency method, accident rate method, and matrix method etc.; the other is methods based on mathematical model, such as analytic hierarchy process (AHP), and fuzzy mathematics method etc.

Methods Based on Data Statistics

Accident Frequency Method

A typical definition of accident frequency method is as follow: "If a certain number of accidents happened in a fixed-length road in a period of time, then defining the fixed-road as road traffic black spot". This method is easy to understand and use, however it does not take traffic flow and road condition and the diathesis of drivers into consideration, so it would misjudges a safe road which has a high traffic flow but low accident rate into a danger road [1, 2, 3].

Accident Rate Method

In this method, for road segment, the evaluation standard is the accident frequency of million vehicles kilometer per year. For intersections, the evaluation standard is the accident frequency of million vehicles per year. When the accident rates of a road segment or an intersection outweigh an acceptable critical value, then the road segment or intersection will be recognized as a black spot. Though this method takes traffic flow and the length of the road into consideration, however it is very easy to cause two situations: the road which has low traffic flow and accident frequency has a high accident rate; but the road which has high traffic flow and accident frequency has a low accident rate. If using this method to identify the black spot only, it also could lead to misjudging a safe road into a danger road, or even missing the more dangerous road [2, 3, 4].

Matrix Method

This method uses accident frequency method and accident rate method as a standard to identify black spot, the horizontal axis represents the accident frequency, and the vertical axis represents the accident rate. Each road is represented by a matrix unit, the position of a matrix unit represents the dangerous level of the road, the most dangerous road has highest accident frequency and accident rate which is situated in the bottom right corner in the matrix. The advantage of this method is the size of the matrix can be determined by the user according to the need. The disadvantage of it is that the method cannot distinguish the road which has a low accident frequency but a high accident rate from the road which has a high accident frequency but a low accident rate essentially; it also does not take into account the decisive effect of critical value and the severity of accident [1, 3, 4].

Equivalent Accident Frequency Method

If taking into account the accidents which have different severity in the same way, and accumulating the number of accidents simply, it will lead to misjudging. In order to identify the black spot accurately, the severity of accident should be taken into account, then the equivalent accident frequency method is proposed. This method distributes value to the injuries and deaths through calculating. However, this method does not take traffic flow and the length of road into consideration, so it has same defects with accident frequency method, and the result is affected by the value to injuries and deaths seriously [3, 4].

Method Based on Mathematical model

Analytic Hierarchy Process (AHP)

Analytic hierarchy process is an evaluation method which combines qualitative analysis with quantitative analysis. The character of this method is that it can make a complex process systematic and hierarchical and modeling. Through analyzing the factors and relation of each factor included in the complex problem, then hierarchy structure model could be established, then the influence degree of each factor to the complex problem could be determined. Therefore, using AHP to identify the factors of road black spot is good for distinguishing the preferential renovation sequence of road black spots, and it is also good for determining a reasonable improvement measures which has significant meaning for improving the traffic safety situation and preventing traffic accidents. However, when using AHP, the weight of each evaluation index is determined based on the experts' experience which has a great subjectivity and the weights also impact the evaluation result [3].

Fuzzy Mathematics Method

Because the understanding of road traffic safety is fuzzy, therefore the obtained evaluation indexes are some qualitative indexes. If using traditional method to identify black spot cannot ensure accuracy, however, fuzzy evaluation model can solve the problem. The specific ideas are as follow: according to the principle of fuzzy transform and maximum membership principle, confirming the factors which are related to the object evaluated, and then making a comprehensive evaluation and the most dangerous object is black spot. This method overcomes the defects of AHP that the indexes are quantitative indexes, the indexes are not considered comprehensively, this method also considers the fuzzy attribute of safety evaluation, and it need not change critical value, so this method is convenient in practical application. However, the evaluation result of the method is a fuzzy value, and there are also some other problems such as the subjectivity and randomness of the obtained indexes etc. [3].

Identification method based on experienced bayesian model

According to this method, the amount of expected accidents of a road is calculated based on the amount of historical accidents and the amount of widely expected accidents of the road.

The formula of experienced Bayesian is as follow:

$$E(\lambda / r) = v \cdot \lambda + (1 - v) \cdot r, \; v = 1/(1 + \lambda / k) \quad (1)$$

In the formula, $E(\lambda/r)$ represents the amount of expected accidents in a particular road; λ represents the amount of historical accidents of the road; v represents the reciprocal of over dispersion parameter.

The advantage of this method is that it discusses the fixed and random factors, but the general statistical data cannot support the method [2].

Through the above analysis, each identification method can identify black spot from different perspective, but they would ignore some factors in practical application, which could decline the accuracy of the identification result. Therefore, each identification method has a certain limitation when using.

Integration and innovation of identification method

Through analyzing the existing identification methods of Road Traffic Black Spot, combining the characteristics of water traffic, then choosing Quality Control Method to recognize water area of intensive traffic accidents and applying integrated influential intensity of accident rate based on Systematical Clustering Algorithm into defining the boundary of the area, an effective evaluation method of black spot identification is established.

Quality control method

When using quality control method to recognize water areas of intensive traffic accidents, assuming in any case, the probabilities of traffic accidents obey Poisson distribution of accident frequency, namely in a particular route, the accidents' probability in a certain time can be calculated as formula (2), then comparing the accident rate of the route with the average accident rate of the whole navigating zone. According to the significant level, confirming the bound of comprehensive accident rate of the intensive accident area.

$$P(n|\mu, t) = \frac{e^{-\mu t}}{n!} (\mu t)^n \quad (n \geq 0) \quad (2)$$

In the formula, t represents time, n represents the amount of accident, μ represents accident frequency of the route.

The mean value and variance of n are calculated as formula (3):

$$E(n) = \mu t, \quad \mathrm{var}(n) = \mu t \quad (3)$$

If the confidence level of the distribution is 95%, then the bound of accident rate is calculated as formula (4) and (5).

$$R^{+} = \lambda + 1.96 \sqrt{\frac{\lambda}{m_i}} + \frac{1}{2} m_i, \quad i = 1,2,3..n \quad (4)$$

$$R^{-} = \lambda - 1.96 \sqrt{\frac{\lambda}{m_i}} - \frac{1}{2} m_i, \quad i = 1,2,3..n \quad (5)$$

In formula (4) and (5), λ represents the accident rate of the whole navigating zone, and $\lambda = \Sigma E(n)/\Sigma m_i$, m_i represents the accumulative standard ships in a certain route [5, 6].

Integrated influential intensity of accident rate based on systematical clustering algorithm

According to the identified intensive water area, using integrated influential intensity of accident rate based on systematical clustering algorithm to define the boundary of black spot.

(1) Numbering the identified intensive water areas and recording them as set $X = \{x_1 \, x_2 \ldots x_i\}$ (i represents the number of intensive water area, $i = 1,2,3..n$), then recording the accidents in x_i as set $G = (G_{i1} \, G_{i2} \ldots G_{im})$ and recording G_{ij} in x_i as a sample, calculating the distance of any two accidents and clustering the two samples that are near to each other, and the like until cannot cluster [7].

(2) Through analyzing the influence factors of water traffic safety, the water traffic safety influence factors index system is established.

(3) The grade of accidents and casualties and financial loss are different in different cluster, it is unable to compare the accidental severity in different cluster only using the amount of accidents. Therefore, it is necessary to standardize the amount of accidents to realize the comparability of accidental severity in different cluster. In this paper using synthetic weighted method to standardize the amount of accidents. The formula is as follow:

$$P = \sum_{i=1}^{n} f_i p_i \quad (6)$$

In the formula, p represents standardized amount of accidents; i represents the sequence number of different grade of accident; f_i represents the weight coefficient of different grade of accident; p_i represents the accident frequency of accident level i; n represents the amount of accident level.

Through calculating the ratio of financial loss and related grade of accident to confirm the value of f_i, regard the weight coefficient of small accident as 1, the weight coefficient of other grade of accident is confirmed by the ratio of unit accident direct financial loss and the unit accident direct financial loss of small accident.

(4) The standard accident rate is calculated by the formula as follow:

$$R = \frac{P}{Q} \tag{7}$$

In the formula, R represents standard accident rate, P represents standardized amount of accidents, Q represents the amount of standard ships.

(5) Confirming the influential intensity of factor K_{ij} to accident rate R_k is ρ_{kij}, dividing the accident rate R_k of the studying cluster by the accident rate R'_k of the similar cluster to the studying cluster which does not include factor K_{ij} to obtain the influential intensity ρ_{kij}, the formula is as follow:

$$\rho_{kij} = \text{accident rate } R_k \text{ of factor } K_{ij} / \text{accident rate } R'_k \text{ of a similar cluster which does not include factor } K_{ij} \tag{8}$$

In the formula, K_{ij} represents sub-factor j of factor i in cluster k, R_k represents standardized accident rate in cluster k, R'_k represents standardized accident rate in the cluster which is similar to cluster k.

(6) The influential intensities of factors in secondary index layer to accident rate are obtained by accumulated multiplying the influential intensities of the related evaluation factors, namely multiplying the influential intensity ρ_{kij} of each sub-factor in factor i of secondary index layer, then the sub influential intensity ρ_{ki} can be obtained, the formula is as follow:

$$\rho_{ki} = \Pi \rho_{kij} \tag{9}$$

(i represents the amount of sub factor in factor i).

(7) Multiplying the sub influential intensity ρ_{ki} of cluster k, the comprehensive influential intensity ρ_k can be obtained, the formula is as follow:

$$\rho_k = \Pi \rho_{ki} = \rho_{ki} \cdot \rho_{ki} \ldots \rho_{ki} \tag{10}$$

(8) The comprehensive influential intensity accident rate of cluster k is calculated as formula (10).

$$C'_k = \rho_k \cdot R_k \tag{11}$$

(9) Confirming the critical value of comprehensive influence intensity accident rate reference the Quality Control Method, the formula is as follow:

$$C_k^+ = A_k + \alpha \sqrt{\frac{A_k}{Q_k}} + \frac{1}{2\overline{Q}_k \times 10} \tag{12}$$

$$C_k^- = A_k - \alpha \sqrt{\frac{A_k}{Q_k}} + \frac{1}{2\overline{Q}_k \times 10} \tag{13}$$

In the formula, C_k represents the critical value of comprehensive influence intensity accident rate in cluster K, C_k^+ is the upper limit value and C_k^- is the lower limit value. A_k represents the comprehensive influence intensity accident rate in a cluster which is similar to cluster K. α represents an statistical constant, if the confidence coefficient is 95%, then the value of α is 1.96. $\overline{Q}_k$ represents the average traffic flow during investigating cluster K.

If the value of a comprehensive influence intensity of a cluster outweighs the upper limit value, then the cluster is confirmed as a black spot [8, 9].

Conclusions

Through analyzing the identification methods of road traffic black spot and combining the characteristics of water traffic, then innovating the existing identification methods and proposing new identification method to identify water traffic black spot which can precisely identify water traffic black spot and the preferential renovation sequence of water traffic black spots, providing a new basis to optimize water traffic environment and guarantee the safety of water traffic and also laying a foundation for the subsequent evaluation work.

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