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Establishment of guest roller safety index based on fuzzy bayesian network

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ABSTRACT

Taking the guest roller in Qiongzhou strait as the research object, the paper analyzes and summarizes the main influence factors to the safety state of guest roller. Take these factors as the nodes to build the Bayesian network topology of guest roller safety assessment model. Obtain the range of evidence nodes with Experts Mark and the nodes probabilities table by fuzzy inferences. then the fuzzy Bayesian network model of guest roller safety assessment is established. Finally, construct the guest roller safety index with Bayesian evidence reasoning. The safety index can represent security situation and trend of guest roller more accurately and dynamically.

KEYWORDS

Guest roller; Shipping; safety evaluation; Fuzzy bayesian network; Evidence reasoning.

INTRODUCTION

Guest Roller transportation has played an important role in the Qiongzhou strait shipping, especially in the aspects of guaranteeing the navigation safety, because it gathers both passenger and cargo transport together, grasps its safety situation and development tendency accurately, which helps management department take reasonable supervisory measure in time by the practical situation. What's more, shipping enterprise and its employees can make correct solutions. At present, the research of guest roller navigation safety is relatively infrequent, the paper take Qiongzhou strait guest roller as the carrier, put forward the safety evaluation of Bayesian network architecture in the guest roller vessel factors, which combines the practical situation of Qiongzhou strait guest roller. It also clears about combined contribution rate of various factors in the navigation safety accidents, the construction and arithmetic of guest roller navigation safety index. Besides, It makes the accurate quantitative of guest roller navigation safety situation come true further, and provides basis of decision making for guest roller safety management.

ESTABLISHMENT OF BAYESIAN NETWORK TOPOLOGY OF GUEST ROLLER SAFETY EVALUATION

The vessel factors indicate the situation of the vessel's mechanical equipment, hull structure and intensity, ship's age, maneuverability, cargo stowage and binding and so on. The reliability of ship's age and facility instruments is the basis of normal navigation. Accidents are unavoidable without seaworthy ship, no matter how good driving skills you have, how seriously to obey the rules. The state of vessel factor determines the vessel itself safety state directly, however, the structural characteristics of guest roller passenger and cargo transport integration determines its specificity of vessel factors.

Selection of factors

According to the current safety management of Qiongzhou strait guest roller shipping and the vessel data provided by the strait shipping co., LTD, analyze the ship factors influencing the navigation safety from the perspective of qualitative and quantitative, the six main factors are selected, which are "ship maintenance", "age of ship", "ship tonnage", "hull structure", "ship equipment" and "vehicle stowage". Ship maintenance reflects vessel's daily maintenance level and safety maintenance status, it also reflects the technology and safety situation of ship equipment. the status of ship equipment decides whether it can navigate safe, which is the objective factor of the Qiongzhou strait shipping accidents. Technical equipment status of old ship is worse than others and it's more likely to have accidents, the age of ship reflects the overall technology equipment situation of Qiongzhou strait ship navigation. Hull structure and the specificity for carrying vehicles make it more dangerous than the normal ones. Hull structure is precondition to ensure safety navigation. Vessel of different tonnage has different rates to have accidents. under the same shipping environment, the tonnage reflects the shipping safety situation to a certain degree. Vehicle stowage reflects the degree of cargo capacity and risk of safety navigation. Hull structure factor include "vehicle tank bulkhead", "initial metacentric height", "speed" and "water tightness". Vehicle stowage factors include "intensity of securing chain", "bell strength", "lashing point" and "trim".

Construction of Bayesian network topology

Safety evaluation is a comprehensive risk assessment process of risk possibility, loss and damage degree of risk event for a system or a subsystem. Shipping traffic accidents possibility is taken as measurement to evaluate navigation safety situation. regard "guest roller shipping safety state" as goal node, take "ship maintenance", "the age of ship", " ship tonnage", "hull structure", "ship equipment" and "vehicle stowage" as the partial node of the goal node. Take "vehicle tank bulkhead", " initial metacentric height", "speed", "water tightness" as the evidence nodes of the partial node- "Hull structure" ; take "intensity of securing chain", "bell strength", "lashing point" and "trim" as the evidence nodes of the partial node- "vehicle stowage". The Bayesian network topology is built, as shown in Figure 1.

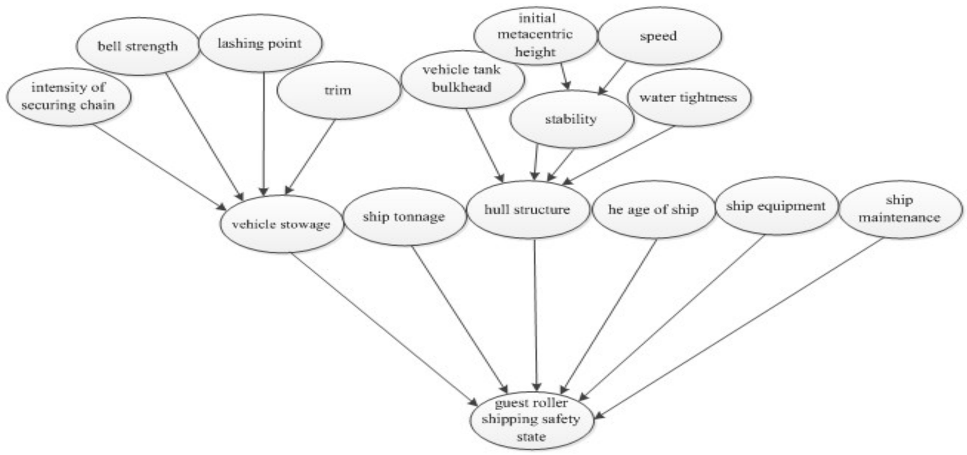

Figure 1 : The Bayesian network topology

Range of the nodes

Define the partial nodes "ship maintenance", "the age of ship", " ship tonnage", "hull structure", "ship equipment" and "vehicle stowage" as X_1, X_2, X_3, X_4, X_5, X_6. Especially, if the partial node doesn't have evidence node, partial node could be treated as evidence node in the network reasoning. Then the evidence nodes are "ship maintenance", "the age of ship", "ship tonnage", "water tightness", "initial metacentric height", "speed", "vehicle tank bulkhead", "ship equipment", "trim", "lashing point", "bell strength", "intensity of securing chain", defined as Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7, Y_8, Y_9, Y_{11}, Y_{12}. Besides, there is intermediate node "stability" defined as Z.

The safety state upon ship maintenance is evaluated with monthly maintenance times-b_{1a}, Quarterly maintenance times-b_{1b} and time between overhaul-b_{1c}. The safety state upon age of ship is evaluated with its actual age-b_2. The safety state upon ship tonnage is evaluated with the actual deadweight-b_3. The safety state upon water tightness is evaluated with water inflow-b_4. The safety state upon initial metacentric height is evaluated with the height value-b_5. The safety state upon speed is evaluated with Velocity Magnitude-b_6. The safety state upon vehicle tank bulkhead is evaluated with that there is the bulkhead or not, marked as b_7. The safety state upon ship equipment is good or bad determined by that weather there is life-saving equipment, marked as b_8. The safety state upon trim is evaluated with Trim difference-b_9. The safety state upon lashing points is evaluated with their usage rate-b_{10}. The safety state upon bell strength is evaluated with its loading intensity-b_{11}. the safety state upon intensity of securing chain is evaluated with its loading intensity-b_{12}. The range of all evidence nodes is as TABLE 1.

SAFETY EVALUATION OF BAYESIAN NETWORK IN THE GUEST ROLLER VESSEL FACTOR

Bayesian network is a way of quantifying risk based on the Bayesian reasoning, but in the reasoning process, a basis of prior probability distribution is necessary. Water traffic safety accidents and risks are both strongly uncertain. Very few accidents and marine risks happen in process of guest roller shipping in Qiongzhou Strait, therefore, the historical data is limited. It's difficult to express possibility with accurate numerical. Then, the expert knowledge could be put to good use. According to experts' evaluation of the linguistic variables, translate the probability of events, described by vague language or the conceptual language, into fuzzy numbers. After ambiguity-resolving, application of Bayesian Networks for reasoning can predict the risk probability of guest roller safety state.

Bayesian Network node probability in the vessel factor based on the Fuzzy Set Theory

The advantages of using fuzzy approaches are: in the fuzzy state where we can't give or get definite numeric, we can bring in the linguistic variable to express experts' evaluation results directly. Dividing the probability into 7 levels: Very High, High, Higher, Medium, Lower, Low and Very Low. Its Fuzzy number form and λ-cut set are shown in the TABLE 2.

TABLE 1 : Range and the probability distribution of evidence nodes

node	**safety state**	**safe → dangerous**		
	safety state level	1		2
Y_1	evaluation criterion	$b_{1a}\geq 12$ and $b_{1b}\geq 4$ and $b_{1c}\leq 1$		$b_{1a}<12$ and $b_{1b}<4$ or $b_{1c}>1$
	probability	0.9		0.1
	safety state level	1	2	3
Y_2	evaluation criterion	$b_2<15$	$15\leq b_2<25$	$b_2\geq 25$
	probability	0.4	0.4	0.2
	safety state level	1	2	3
Y_3	evaluation criterion	$b_3\geq 6000$	$3000\leq b_3<6000$	$b_3<3000$
	probability	0.3	0.5	0.2
	safety state level	1	2	3
Y_4	evaluation criterion	$b_4<5$	$5\leq b_4<10$	$b_4\geq 10$
	probability	0.224	0.607	0.169
	safety state level	1		2
Y_5	evaluation criterion	$0.3\leq b_5<1$		$b_5<0.3$， $b_5\geq 1$
	probability	0.98		0.02
	safety state level	1		2
Y_6	evaluation criterion	$b_6<5$	$5\leq b_6<10$	$b_6\geq 10$
	probability	0.233	0.687	0.08
	safety state level	1		2
Y_7	evaluation criterion	exist		no
	probability	0.555		0.445
	safety state level	1		2
Y_8	evaluation criterion	exist		no
	probability	0.887		0.113
	safety state level	1		2
Y_9	evaluation criterion	$0.2\leq b_9<0.5$		$b_9<0.2$, $b_9\geq 0.5$
	probability	0.8		0.2
	safety state level	1		2
Y_{10}	evaluation criterion	$b_{10}\geq 50\%$		$b_{10}<50\%$
	probability	0.78		0.22
	safety state level	1		2
Y_{11}	evaluation criterion	$b_{11}\geq 120$		$b_{11}<120$
	probability	0.9		0.1
	safety state level	1		2
Y_{12}	evaluation criterion	$b_{12}\geq 120$		$b_{12}<120$
	probability	0.752		0.248

TABLE 2 : Fuzzy number form and λ-cut set

Description	Fuzzy number form	λ-cut set
Very High (VH)	f_{VL}=(0.0， 0.1， 0.2)	f^{λ}_{VL}=[0.1λ+0， -0.1λ+0.2]
High (H)	f_{L}=(0.1， 0.2， 0.3)	f^{λ}_{L}=[0.1λ+0.1， -0.1λ+0.3]
Higher(FH)	f_{FL}=(0.2， 0.3， 0.4， 0.5)	f^{λ}_{FL}=[0.1λ+0.2， -0.1λ+0.5]
Medium (M)	f_{M}=(0.4， 0.5， 0.6)	f^{λ}_{M}=[0.1λ+0.4， -0.1λ+0.6]
Lower (FL)	f_{FH}=(0.5， 0.6， 0.7， 0.8)	f^{λ}_{FH}=[0.1λ+0.5， -0.1λ+0.8]
Low (L)	f_{H}=(0.7， 0.8， 0.9)	f^{λ}_{H}=[0.1λ+0.7， -0.1λ+0.9]
Very Low (VL)	f_{VH}=(0.8， 0.9， 1.0)	f^{λ}_{VH}=[0.1λ+0.8， -0.1λ+1]

To use Fuzzy numeric quantifying the probability of whole event better, it's necessary to synthesize a number of experts' evaluation results. The paper adopts arithmetic method to synthesize the results, N experts comprehensive evaluation can express as:

$$P(i) = \frac{f_{i1} \oplus f_{i2} \oplus \cdots \oplus f_{im}}{n} \quad i = 1, 2, \cdots, m \tag{1}$$

In the Formula 1, P_i represents the probability of the event i; f_{ij} are the fuzzy numeric of the event j evaluated by the expert I; m is the number of the event. According to the experts experience and study data, based on the Bayesian model of Qiongzhou strait guest roller safety state, we translate all the experts' advice into Fuzzy probability numeric, make every expert have same weight, use arithmetic method to get Fuzzy probability numeric of every node.

Take "speed" node as example, 10 experts give language description of Fuzzy probability numeric, which show in the TABLE 3. Assume the weight and adopt arithmetic method to get synthetic fuzzy probability numeric.

TABLE 3 : The description of safety state of "speed"

Factor Expert	speed＜5kn	5kn＜speed＜10kn	speed＞10kn
1	high	medium	very low
2	higher	very low	low
3	high	higher	lower
4	higher	medium	medium
5	medium	low	very low
6	high	medium	lower
7	high	higher	low
8	high	medium	very low
9	higher	low	lower
10	high	lower	low

(2)

In the Fuzzy set, ambiguity-resolving is the process to get a single numeric that can represent the whole Fuzzy set most. The paper adopts integral value method to resolve Fuzzy set, uses the operation of λ-cut set to handle fuzzy.

According to the description from the expert, the Fuzzy number can be obtained with the λ-cut set and Formula 2. In the Fuzzy set, ambiguity-resolving is the process to get a single numeric that can represent the whole Fuzzy set most. The paper adopts integral value method to resolve Fuzzy set, uses the operation of λ cut set to handle fuzzy number, which is easy to understand and calculate. Take optimizing index ε to reflect final decision. Assuming *P* is the fuzzy number of L-R model, the Fuzzy value of Fuzzy number *P* is

$$I(P)=(1-\varepsilon)I_R(P)+\varepsilon I_L(P) \quad (3)$$

In the Formula 3, $\varepsilon \in [0,1]$ is the optimistic coefficient, when ε=0 and ε=1, *I(P)* are corresponding the upper and lower bound of *P* Fuzzy value. When ε =0.5, *I(P)* is representative value of the P Fuzzy value. Adopting Fuzzy method to get representative value of the Prior probability, when ε=0.5, according to the Formula 3, we can get the Prior probability of "speed" node: *P* (speed＜5 kn)=0.233. Similarily, *P*(5kn＜speed ＜10 kn)=0.687, *P*(speed＞10kn)=0.08. Put the data into calculating the Marginal probability distribution of "trim", "lashing point", "intensity of securing chain" and "bell strength", "initial metacentric height", "speed", "water tightness", "vehicle tank bulkhead", "ship tonnage", "the age of ship", "ship maintenance", and "life-saving equipment" these 12 nodes. The results are shown as TABLE 3.

Evidential reasoning of Fuzzy Bayesian Network model

Through the previous work, on the basis of Bayesian network modeling steps, we confirm the Bayesian Network node of Qiongzhou strait guest roller in the vessel factors, construct the Bayesian network hierarchical structure of the guest roller safety state, and we get probability table of each node in the Bayesian network, which forms the Bayesian network evaluation model evaluating the Qiongzhou strait navigation safety, and we can make safety risk prediction.

The Fuzzy Bayesian network generalizes the Continuous nodes variable to the Fuzzy nodes variable. Guest roller's every vessel factor can be expressed by a limited nodes set $X=\{x_1, x_2, \ldots, x_n\}$, *Xi* express every possible state set of xi. Assuming that $x_i \in X$ can be fuzzified as a fuzzy random variable u_i and u_i inherits x_i all the possible state. So the fuzzy set of x_i is:

$$U_i=\{\tilde{X}_{i1},\tilde{X}_{i2},\ldots,\tilde{X}_{in}\} \quad (4)$$

In the formula 5: r_1 is the fuzzy state number of u_i; represents fuzzy state *j* of u_i , can be shown as:

$$\tilde{X}_{ij}=\{x,\mu_{ij}(x) \mid x\in X_i\} \quad (5)$$

In the formula 6, $\mu_{ij}(x)$ represents the degree of membership of variable x in the Xi, which belongs to the u_i. It can be showed by the conditional probability of with a given condition X.

$$\mu_{ij}(x)=P(\tilde{X}_{ij} \mid x) \quad (6)$$

$$0\le \mu_{ij}(x)\le 1,\sum_{j=1}^{r_i}\mu_{\tilde{X}_{ij}}(x)=1 \quad (7)$$

According to the threshold value division of ship factor state and marginal distribution, combined with the experts' description translated into fuzzy number, we can calculate the conditional probability of partial nodes evidence nodes by the equation, which are shown in the TABLE 4 to TABLE 6.

TABLE 4 : Conditional probability of partial node “X6”and evidence node “Y_9” “Y_{10}”“Y_{11}”“ Y_{12}”

Y_9	Y_{10}	Y_{11}	Y_{12}	$P(X_6=1\| Y_9;Y_{10};Y_{11};Y_{12})$	$P(X_6=2\|Y_9;Y_{10};Y_{11};Y_{12})$
High	High	High	High	0.9	0.1
Low	High	High	High	0.8	0.2
…	…	…	…	…	…
High	Low	Low	Low	0.2	0.8
Low	Low	Low	Low	0.1	0.9

TABLE 5 : Conditional probability of intermediate node “Z” and evidence node “Y_5” “Y_6”

Y_5	Y_6	$P(Z=1\|Y_5;Y_6)$	$P(Z=2\|Y_5;Y_6)$
High	Low	0.9	0.1
Low	Low	0.8	0.2
…	…	…	…
Low	Low	0.1	0.9

TABLE 6 : Conditional probability of partial node “X_4”and evidence node “Y_4”“ Z”“Y_7”

Y_4	Z	Y_7	$P(X_4=1\|Y_4;Z;Y_7)$	$P(X_4=2\|Y_4;Z;Y_7)$
High	High	High	0.9	0.1
Medium	Low	High	0.65	0.35
…	…	…	…	…
Medium	Medium	Medium	0.1	0.9

TABLE 7 : Conditional probability of goal node of “guest roller safety state”and partial node “X_1” “X_2”“ X_3” “X_4” “X_5” “X_6”

X_1	X_2	X_3	X_4	X_5	X_6	$P(safe=ture\| X_1; X_2; X_3; X_4; X_5; X_6)$	$P(accident=ture\| X_1; X_2; X_3; X_4; X_5; X_6)$
High	High	High	High	High	High	0.9	0.1
Low	High	High	High	High	High	0.8	0.2
High	Medium	High	High	High	High	0.8	0.2
…	…	…	…	…	…	…	…
High	Low	Medium	Medium	Low	Medium	0.1	0.9
Low	Low	Medium	Medium	Low	Medium	0.1	0.9

Evidence reasoning of fuzzy Bayesian Network

According to the conditional probability calculated by the evidence node and partial node, we adopt joint probability distribution to get the probability of goal node “Qiongzhou strait guest roller safety state”.

P (guest roller is safe=true)

$=\sum P(X_1; X_2;X_3;X_4;X_5;X_6;$ guest roller is safe =true)

$= P (X_1=1;X_2=1;X_3=1;X_4=1;X_5=1;X_6=1;$ guest roller is safe =true)+

$P (X_1=2;X_2=1;X_3=1;X_4=1;X_5=1;X_6=1;$ guest roller is safe=true) +…+

$P (X_1=2;X_2=2;X_3=2;X_4=2;X_5=3;X_6=1;$ guest roller is safe =true) **(8)**

In the Bayesian Network model, it is suggested that the nodes $X_1;X_2;X_3;X_4;X_5;X_6$ are mutual independent, then:

$$P\ (\text{guest roller is safe}\ ;X_1=1;X_2=1;X_3=1;X_4=1;X_5=1;X_6=1) = P(X_1=1)\cdot P(X_2=1)\cdot P(X_3=1)\cdot P(X_4=1)\cdot P(X_5=1)\cdot P(X6=1)\cdot P(\text{guest roller is safe} \mid X_1=1;X_2=1;X_3=1;X_4=1;X_5=1;X_6=1) \quad \mathbf{(9)}$$

Using each node's prior probability and conditional probability in section B, and combine Formula (8) and (9), software Matlab is used to construct Bayesian network structure. Firstly, illustrate the connection relationship between the nodes, and set conditional probability table. Then input the evidence, and calculate posterior probability of every single node. Finally, we can reason (definite data code are shown in the Appendix IV), solve and get Qiongzhou state guest roller safety sate. Main program code of reasoning is as following Figure 2 to Figure 4.

```
% input the probability of evidence nodes  into Bayesian Network
bnet.CPD{b9}=tabular_CPD(bnet,b9,[0.8,0.2]);
bnet.CPD{b10}=tabular_CPD(bnet,b10,[0.78,0.22]);
bnet.CPD{b12}=tabular_CPD(bnet,b12,[0.752370264928798,0.247629735071202]);
bnet.CPD{b11}=tabular_CPD(bnet,b11,[0.100042277032219,0.899957722967781]);
bnet.CPD{b5}=tabular_CPD(bnet,b5,[0.979689885639999,0.0203101143600012]);
bnet.CPD{b6}=tabular_CPD(bnet,b6,[0.232857142857143,0.687142857142857,0.08]);
bnet.CPD{b4}=tabular_CPD(bnet,b4,[0.224285714285714,0.607142857142857,0.168571428571429]);
bnet.CPD{b7}=tabular_CPD(bnet,b7,[0.555335623457386,0.444664376542614]);
bnet.CPD{b3} =tabular_CPD(bnet,b3,[0.3,0.5,0.2]);
bnet.CPD{b2} =tabular_CPD(bnet,b2,[0.4,0.4,0.2]);
bnet.CPD{b1}=tabular_CPD(bnet,b1,[0.9,0.1]);
bnet.CPD{b8}=tabular_CPD(bnet,b8,[0.887366844870106,0.112633155129894]);
```

Figure 2 : Matlab program code (I)

```
N=12;  %  There are 12 nodes in the safety evaluation model
dag = zeros(N,N);
%  Define the number of the node
b9=23;b10=24;b12=25;b11=26;b5=27;b6=28;b4=29;WX=30;b7=31;b1=32;b2=33;b8=34;B4=35;b3=36;B6=37;
CBYS=38;
%Connect the evidence node, partial node and target node
dag(b9,B6)=1;dag(b10,B6)=1;dag(b12,B6)=1;dag(b11,B6)=1;dag(b5,WX)=1;
dag(b6,WX)=1;dag(b4,B4)=1;dag(WX,B4)=1;dag(b7,B4)=1;dag(b1,CBYS)=1;
dag(b2,CBYS)=1;dag(b8,CBYS)=1;dag(B4,CBYS)=1;dag(b3,CBYS)=1;
dag(B6,CBYS)=1;
dag(CBYS, Guest Roller safety state)=1;
%Establish the Bayesian Network
discrete_nodes = 1:N;
%Determine the state level of each node
node_sizes=[2,3,3,3,2,3,2,2,2,2,2,2,];
%Connect the name to node bnet = mk_bnet(dag, node_sizes);
bnet=mk_bnet(dag,node_sizes,'names',{ 'b9','b10','b12','b11','b5','b6','b4','WX','b7','b1','b2','b8','B4','b3','B6','CBYS', Guest Roller safety state '},
'discrete',discrete_node);
```

Figure 3 : Matlab program code (II)

```
% input the conditional probability into Bayesian Network
bnet.CPD{B6}=tabular_CPD(bnet,B6,[1,0.8,0.8,0.7,0.8,0.7,0.7,0.6,0.8,0.7,0.7,0.6,0.8,0.6,0.6,0,0,0.2,0.2,0.3,0.2,0.3,0.3,0.4,0.2,0.3,0.3,0.4,0.2,0.4,0.4,1]);
bnet.CPD{Z}=tabular_CPD(bnet,WX,[0.9,0.8,0.65,0.5,0.35,0.1,0.1,0.2,0.35,0.5,0.65,0.9]);
bnet.CPD{B4}=tabular_CPD(bnet,B4,[1,0.9,0.89,0.87,0.8,0.78,0.7,0.64,0.58,0.2,0.1,0,0,0.1,0.11,0.13,0.2,0.22,0.3,0.36,0.42,0.8,0.9,1]);
bnet.CPD{CBYS}=tabular_CPD(bnet,CBYS,[1,0.1,0.99,0.09,0.97,0.08,0.99,0.09,0.98,0.08,0.96,0.07,0.8,0.1,0.79,0.1,0.77,0.1,0.79,0.1,0.78,0.1,0.76,0.1,0.99,0.09,0.98,0.08,0.96,0.07,0.98,0.08,0.97,0.07,0.95,0.06,0.6,0.1,0.59,0.1,0.57,0.1,0.59,0.1,0.58,0.1,0.56,0.1,0.98,0.08,0.97,0.07,0.95,0.06,0.97,0.07,0.96,0.06,0.94,0.05,0.4,0.1,0.39,0.1,0.37,0.1,0.39,0.1,0.38,0.1,0.36,0.1,0.99,0.09,0.98,0.08,0.96,0.07,0.98,0.08,0.97,0.07,0.95,0.06,0.6,0.1,0.59,0.1,0.57,0.1,0.59,0.1,0.58,0.1,0.56,0.1,0.79,0.1,0.78,0.1,0.76,0.1,0.78,0.1,0.77,0.1,0.75,0.1,0.4,0.1,0.39,0.1,0.37,0.1,0.39,0.1,0.38,0.1,0.36,0.1,0.97,0.07,0.96,0.06,0.94,0.05,0.77,0.06,0.95,0.05,0.93,0.04,0.2,0.1,0.19,0.1,0.17,0.1,0.19,0.1,0.18,0.1,0.16,0.1,0,0.9,0.01,0.91,0.03,0.92,0.01,0.91,0.02,0.92,0.04,0.93,0.2,0.9,0.21,0.9,0.23,0.9,0.21,0.9,0.22,0.9,0.24,0.9,0.01,0.91,0.02,0.92,0.04,0.93,0.02,0.92,0.03,0.93,0.05,0.94,0.4,0.9,0.41,0.9,0.43,0.9,0.41,0.9,0.42,0.9,0.44,0.9,0.02,0.92,0.03,0.93,0.05,0.94,0.03,0.93,0.04,0.94,0.0600000000000001,0.95,0.6,0.9,0.61,0.9,0.63,0.9,0.61,0.9,0.62,0.9,0.64,0.9,0.01,0.91,0.02,0.92,0.04,0.93,0.02,0.92,0.03,0.93,0.05,0.94,0.4,0.9,0.41,0.9,0.43,0.9,0.41,0.9,0.42,0.9,0.44,0.9,0.21,0.9,0.22,0.9,0.24,0.9,0.22,0.9,0.23,0.9,0.25,0.9,0.6,0.9,0.61,0.9,0.63,0.9,0.61,0.9,0.62,0.9,0.64,0.9,0.03,0.93,0.04,0.94,0.0600000000000001,0.95,0.23,0.94,0.05,0.95,0.0700000000000001,0.96,0.8,0.9,0.81,0.9,0.83,0.9,0.81,0.9,0.82,0.9,0.84,0.9]);
%  reasoning
engine =jtree_inf_engine(bnet);
evidence=cell(1,N);
[engine, loglik] = enter_evidence(engine, evidence);
m=marginal_nodes(engine,Guest Roller Safety State)
```

Figure 4 : Matlab program code (III)

After network training, guest roller safety assessment model based on Bayesian network is successfully built. Input the state of node into the model, the probability of the guest roller under safe state could be work out.

CONSTRUCTION OF SAFETY INDEX

As an important measurable indicator, index reflects the change in direction and degree of overall phenomenon synthetically and intuitively. It also analyses the impact on the overall direction and degree, which are caused by factors in the change of overall phenomenon. Through constructing the Bayesian network model evaluating the guest roller vessel safety state and reasoning algorithm, we have obtained the impact on the direction and degree of synthetical safety state, which are led by the state of every vessel factor. However, the safety index of strait guest roller navigation still need to reflects the change in direction and degree of safety state synthetically and intuitively. So it’s essential to confirm reasonable base period.

Guest roller navigation safety index compare the probability of base period goal node to the goal node probability calculated in real-time supervision, and then to get a more accurate conclusion. In combination with the quarter of practical condition of Qiongzhou strait guest roller, the base period condition is shown in TABLE 8.

Putting the base period data into the Bayesian evaluation model, we can get probability P occurred in the two safety condition this period.

TABLE 8 : Node state of base period

node	**ship maintenance**	**he age of ship**	**intensity of securing chain**	**vehicle tank bulkhead**	**initial metacentric height**	**water tightness**
state	1	2	1	1	1	1
nede	speed	ship equipment	ship tonnage	bell strength	lashing point	trim
state	2	1	1	1	1	1

Putting the base period data into the Bayesian evaluation model, we can get probability P occurred in the two safety condition this period. Taking the influence of different safety condition into account, it’s easy to obtain the synthetical condition of Qiongzhou strait guest roller safety. The safety index can be calculated by the following Formula (10).

IS=**(10)**

In the formula: *IS* represents the index of guest roller safety condition; P_0 represents the probability of safe state in the base period safety state; P_i represents t probability of safe state in the real-time supervision.

It’s the international practical to set base period safety index as 10000, which is easy to understand, so we can get the synthetical safety condition in the base period. The index calculated by the formula can reflect the developing tendency of real-time safety condition. when the index is 10000 in the base period and 7000 in the report period, we consider that the real-time safety condition in Qiongzhou strait is worse than the base period. The safety state in the base period can be set based to the guest roller navigation actual condition.

EMPIRICAL RESEARCH

Taking the navigating guest roller in Qiongzhou strait on January15th, 2012 as example and calculate its safety index. “Qiong Lin Gao 03739” near the coordinate 1# in Qiongzhou strait, the approximate position is 20°12’.2N, 110°25’.2E (overall length: 27.6 meters;6meters in width; DWT is 86; there are five crew on board), the speed is 4 knots.[The information is from Haiko Maritime Safety Administration]

Owing to the known name of the vessel, the node state of the other factors can be inquired in management system. According to the evaluating table of evidence node condition, we can translate the mentioned monitoring information into node state value of Bayesian network, specific monitoring value are shown in following TABLE 9.

TABLE 9 : Node state monitored in real-time

node	ship maintenance	he age of ship	intensity of securing chain	vehicle tank bulkhead	initial metacentric height	water tightness
state	1	2	1	1	1	1
nede	speed	ship equipment	ship tonnage	bell strength	lashing point	trim
state	1	1	1	1	2	1

Input the state level of nodes monitored in real-time as Figure 5.

```
   % input evidence node to reasoning
   engine =jtree_inf_engine(bnet);
   evidence{b1}=1;evidence{b2}=2;evidence{b3}=1;evidence{b4}=1;
evidence{b5}=1;evidence{b6}=1;evidence{b7}=1;evidence{b8}=1;
    evidence{b9}=1; evidence{b10}=2;evidence{b11}=1; evidence{b12}=1;
   [engine, loglik] = enter_evidence(engine, evidence);
   m=marginal_nodes(engine, Guest Roller Safety State)%    probability of target node under the
above condition
   m.T()
```

Figure 5 : Reasoning of monitoring guest roller safety

Input the state level of nodes of base period, as Figure 6 ：

```
   %input evidence node to reasoning
   engine = jtree_inf_engine(bnet);
   evidence{b1}=1;evidence{b2}=2;evidence{b3}=1;evidence{b4}=1;
evidence{b5}=1;evidence{b6}=1;evidence{b7}=2;evidence{b8}=1;
    evidence{b9}=1; evidence{b10}=1;evidence{b11}=1; evidence{b12}=1;
   [engine, loglik] = enter_evidence(engine, evidence);
   m=marginal_nodes(engine,QZHXKGLAQZK)%       probability of target node under the
above condition
   m.T()
```

Figure 6 : Reasoning of guest roller safety of base period

After reasoning, the probability of guest roller real-time safety state is: P_i =0.8456. The probability of guest roller base period safety state is: P_0= 0.7589, safety index of base period -SI_0 equals to 10000. So the guest roller real-time safety index *IS* is:

IS==12445

It can be seen that the real-time safety index is higher than the base period index. Therefore, the safety state of guest roller is in good condition and will continue in the better direction.

CONCLUSION

Through the research and analysis, Bayesian network structure based on the node of guest roller vessel factor could be constructed. in the case of enough accident data, it’s easy to proceed to the evidential reasoning of Bayesian network model directly, and to get the contribution rate caused by the accident factors, then to ensure the safety risks. However, in the case of insufficient accident data, firstly we need ensure the connected relation among each node based on the experts' experience. Then translate the impact on the vessel safety state caused by vessel factors into fuzzy language, and quantify them in the light of Delphi method and Fuzzy reasoning. The conditional probability table can be established according to the conditional probability of evidence node, partial node and intermediate node, with which, the network model is formed. Finally, we can reason the safety and risk probability of goal node by means of the input evidence of single node. Based on Bayesian network model, select the base period, construct the safety index which not only reflects the impact on the direction and degree of safety state caused by the vessel factors' state, but also reflects the change in direction and degree of safety state synthetically and intuitively. The index helps shipping management department, enterprise and employee grasp the safety state of guest roller in time, and it's beneficial to raise the level of safety management and safety efficiency of guest roller.

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