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Risk Analysis of Ship Foundering Using The Hybrid Causal Logic Methodology

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Outline

1. Background

2. Methodology

3. Case study

4. Result and discussion

5. Conclusions

Background

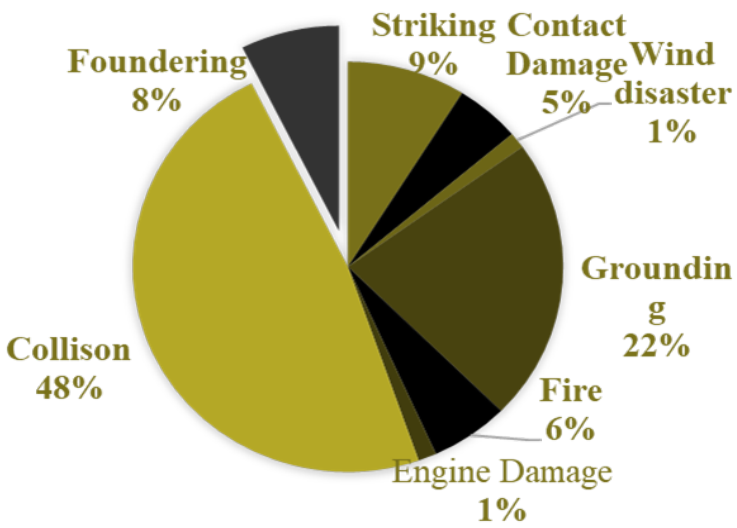
Background

The Belt and Road

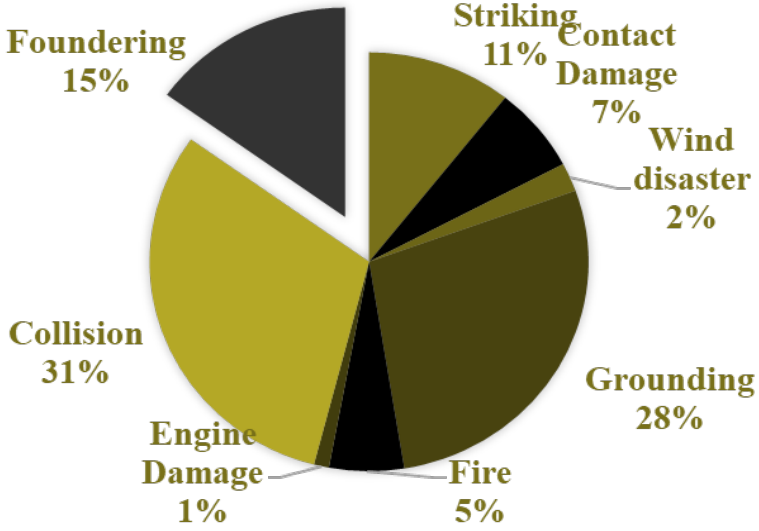
Foundering accident

- **Policy:** The **Belt and Road Initiative** and the **Yangtze River economic zone policy** have been proposed and promoted by China, water transportation is playing an important role.
- **Economy:** Low cost and growing traffic demand
- **Safety:** High risk and serious consequences, a total of **196** cases of maritime traffic accidents occurred in China in 2016. There were **203** deaths and **82** wrecks. (According to the statistics of Ministry of Transport of the People's Republic of China (MOT)).

Background



Accidents happened on the Yangtze River from 2013 to 2016



Serious accidents happened on the Yangtze River from 2013 to 2016

Ship foundering is one of the typical scenes of water traffic accidents.

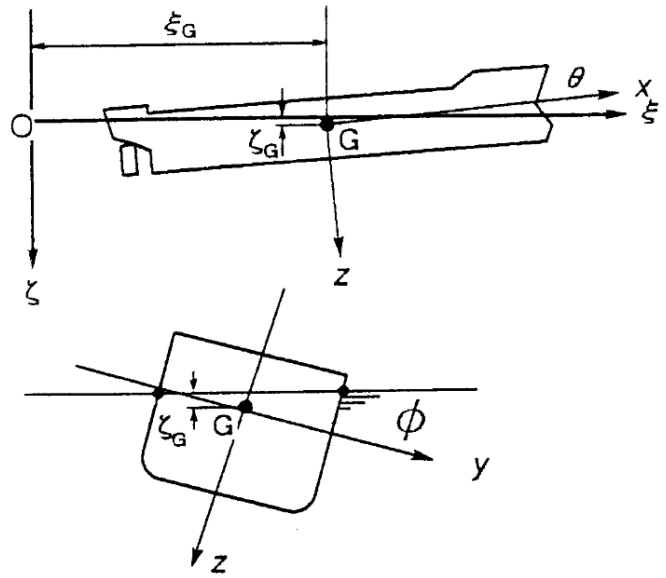
On June 1, 2015, “Oriental Star” ship foundering in the waters of Jianli, Hubei province. It is the most serious accident in Yangtze river from 2013 to now, there were **442** deaths and only **12** survived.

So its serious consequences is worth our attention.

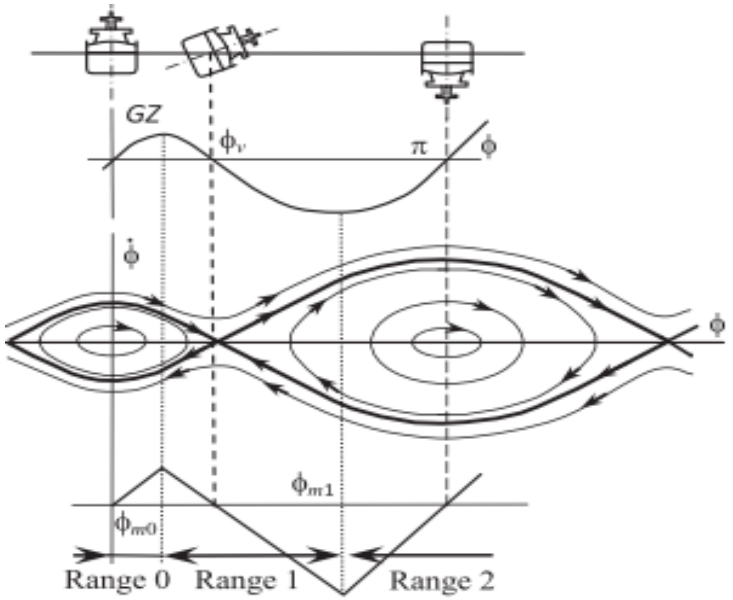
*According to the statistics of Ministry of Transport of the People's Republic of China (MOT)

Methodology

Methodology



Hamamoto M, Panjaitan P J, Munif A. A Probabilistic Approach to Capsize of Ship in Random Astern Seas :[J]. Journal of the Japan Society of Naval Architects & Ocean Engineers, 2009, 1997(182):161-169.

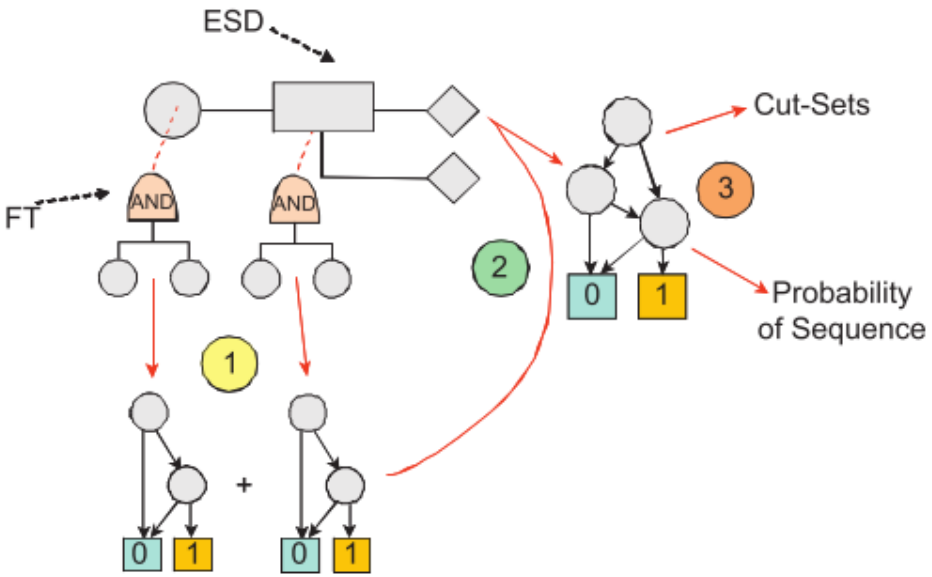


V. Belenky, K. Weems and W.-M. Lin. "Split-time method for estimation of probability of capsizing caused by pure loss of stability", Ocean Engineering, 122, pp. 333-343, (2016).

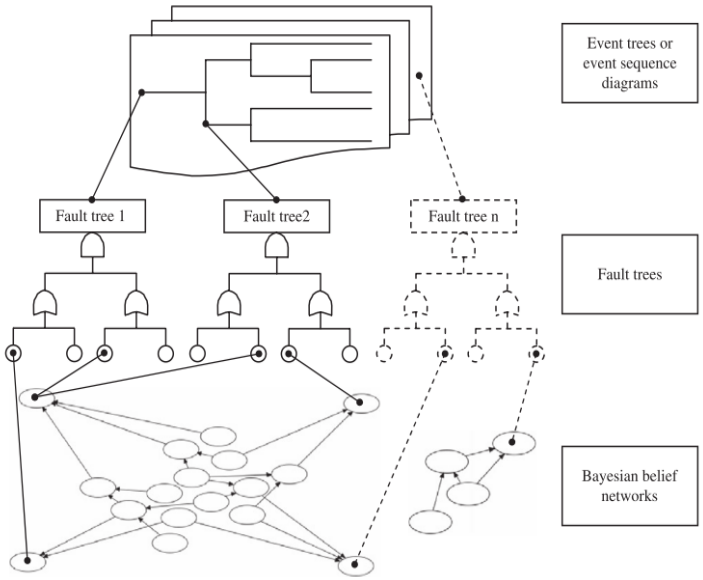
The risk of ship foundering was analyzed including: mathematical method, simulation and the safety field model.

However, it is unable to clearly or comprehensively discuss human and organizational factors, and non-human factors.

Methodology



Z. Mohaghegh, R. Kazemi and A. Mosleh. "Incorporating organizational factors into Probabilistic Risk Assessment (PRA) of complex socio-technical systems- A hybrid technique formalization", Reliability Engineering & System Safety, 94, pp. 1000-1018, (2009).

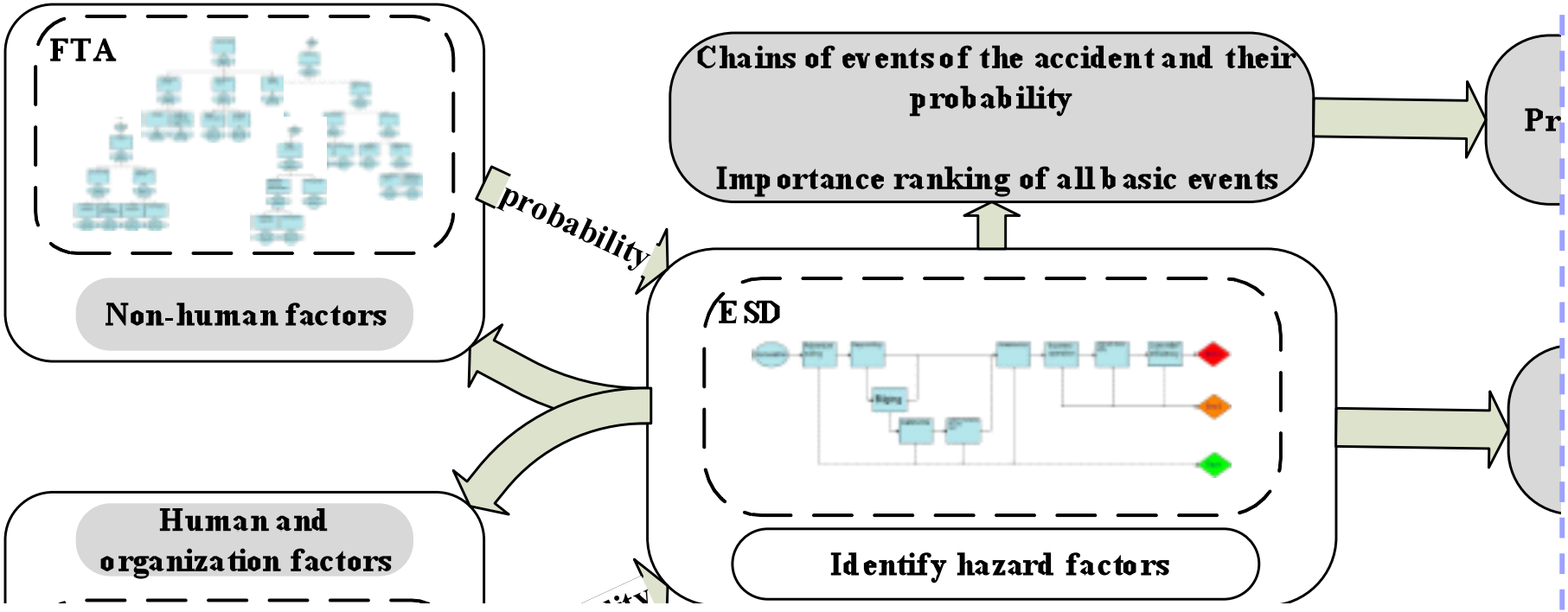


W. Røed, A. Mosleh, J. E. Vinnem and T. Aven. "On the use of the hybrid causal logic method in offshore risk analysis", Reliability Engineering & System Safety, 94, pp. 445-455, (2009).

Recently, a methodology called hybrid causal logic (HCL) has been developed, allowing **Bayesian Belief Networks** (BBNs) to provide input information to **fault trees** (FTs) and **event sequence diagram** (ESD).

Roed and Groth used the methodology to offshore industry and airline business.

Methodology



Framework and Flowchart

A methodology **Hybrid Causal Logical**(HCL) is utilized, the framework consists of three layers:
Event Sequence Diagram (ESD), **Fault Tree Analysis**(FTA), and **Bayesian Belief Network** (BBN).

Methodology

- **Event Sequence Diagram (ESD),**

The ESD is a graphical, probabilistic approach to model and analyze accidents, it is used to estimate the evolution of a complex accident.

- In qualitative analysis
- In quantitative analysis

- **Fault tree analysis (FTA)**

The FTA is a typical method and an accidental evolutionary logic analysis tool used to estimate the safety and reliability of a complex system.

- In qualitative analysis
- In quantitative analysis

- **Bayesian Belief Network (BBN)**

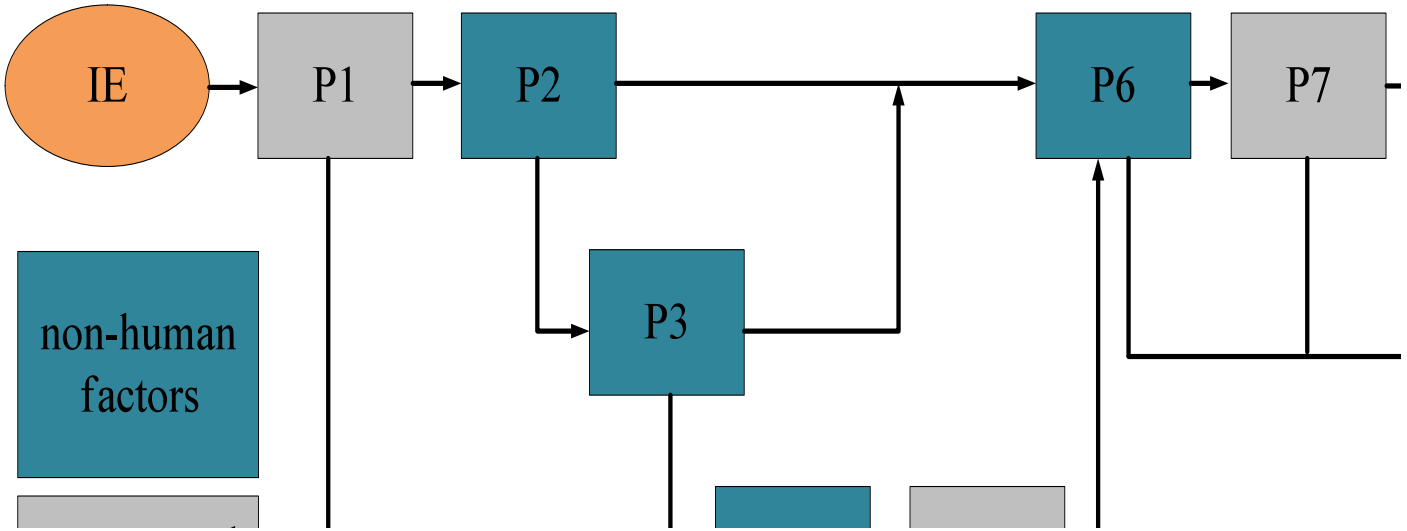
The BBN is a graphical model that describes the causal relationships between the key factors in a system and one or more final outputs.

- In quantitative analysis

Case Study

ESD Model

An ESD model presented in this paper is based on analyzing 28 accident reports from State Administration of Work Safety and China MSA.
The model shows the evolution of a ship's foundering accident in bad weather.



ESD Model of Ship Foundering

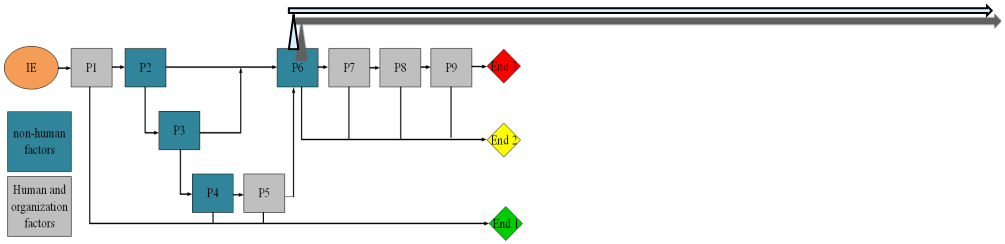
Bad weather(IE), Sailing(P1), Cargo shifting(P2), Bilging(P3), Cabin fire(P4), Fire water left in the cabin(P5), Unstable ship(P6), Emergency handling capacity(P7)，
Self-rescue ability(P8), Rescue efficiency(P9)

Data

Node	Name	Probability	Sources
IE	Bad weather	0.167	China MSA statistics
P1	Sailing	0.20	Assumed 0.20
P2	Cargo shift	Linked to FT	Given by experts 0.01
P3	Bilging	Linked to FT	Assumed 0.10
P4	Cabin fire	Linked to FT	Calculated 0.11
P5	Fire water left in the cabin	Linked to BBN	Given by experts 0.20
P6	Unstable ship	Linked to FT	Calculated 0.20
P7	Emergency handling capacity	Linked to BBN	Calculated 0.11
P8	Self-rescue ability	Linked to BBN	Calculated 0.09
P9	Rescue efficiency	Linked to BBN	Calculated 0.39

Data of ESD model comes from:(1) Maritime Safety Administration of the People' Republic of China (China MSA) statistics, (2) the later FT models, (3) the later BBN models, (4) assumptions.

FT Model

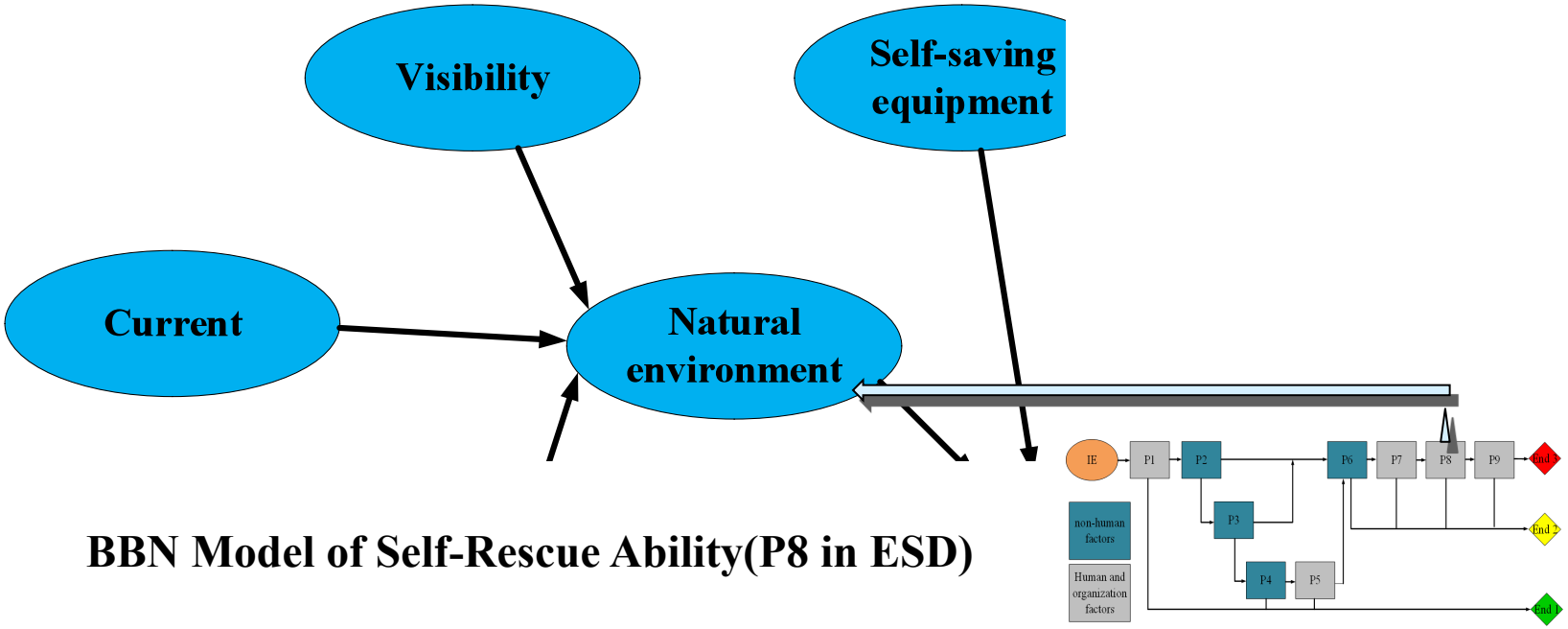


FT Model of Unstable ship(P6 in ESD model)

This paper models the process of generating branches of some ESD nodes using fault trees. some non-human factors in ESD is linked to the FT as the top event.

*The data comes from:(1) Maritime Safety Administration of the People' Republic of China (China MSA) statistics, (2) the later BBN models, (3) assumptions

BBN Model



BBN Model of Self-Rescue Ability(P8 in ESD)

BBN is used to quantify the human and organizational factors in ESD.

These parameters are from 28 foundering accidents reported according to China MSA and State Administration of Work Safety.

∗The prior distributions of all root nodes can be obtained from the statistics of accidents. The CPTs of “Natural environment” and “Self-rescue ability” given by 4 experts and 28 accident reports.

Result and Discussion

Result and Discussion

Probability of Different Consequence

Ranking	Consequence	Probability
1	Safe	0.0537879
2	Light consequence	0.0018281
3	Serious consequence	0.0000507

- The probability of a serious ship foundering accident is very low compared with light ship foundering under bad weather condition.
- Due to the particularity of water transportation, some measures should be adopted to reduce harm consequence.

Result and Discussion

Chains of Events of Ship Foundering

Ranking	Chains of Events		
1	Bad weather, Adventure sailing	Liquefaction of cargoes	Bad emergency handling capacity, Poor self-rescue ability, Low rescue efficiency
2		Incorrect operation	
3		Incorrect operation, Tough navigation environment	
4		Incorrect operation, Ship defects	
5		Equipment short circuit, Incorrect operation	
6		Equipment overload, Incorrect operation	
7		Combustible goods, Incorrect operation	
8		Fuel leakage, Incorrect operation	
9		Combustible goods, Mechanical temperature is too high, Incorrect operation	
10		Combustible goods, Incorrect operation	
11		Fuel leakage, Mechanical temperature is too high, Incorrect operation	
12		Fuel leakage, Incorrect operation	

Risk of the chain of events is highest which contains: bad weather, adventure sailing, liquefaction of cargoes, bad emergency handling capacity, bad self-rescue ability and low rescue efficiency.

Result and Discussion

Importance Measures of Basic Events(TOP 10)

NO	Basic event	RAW	Vesely-Fussel	RRW	Birnbaum
1	Illegal modification	1	0.22	1	0
2	Incorrect operation	1.30488	0.5	1.307611	0
3	Equipment short circuit	1.22295	0.034243	1.006464	0.002127
4	Equipment overload	1.22295	0.017121	1.003176	0.002097
6	Mechanical sparks	1	0.056	1	0
7	High mechanical temperature	1	0.07	1	0
8	Tough navigation environment	1.182777	0.390317	1.098931	0.00253
9	Ship defects	1.218298	0.097464	1.01935	0.002201
10	Liquefaction of cargoes	1.455579	0.655011	1.594252	0.007682

Liquefaction of cargoes is **a main risk** in the ship foundering accident in bad weather, along with incorrect operation.

It is consistent with the result of the chain of events and the accident reports.

Result and Discussion

These measures should be accepted in order to minimize the probability and reduce harm consequence of those undesired events:

- ***Monitoring the indicators related to the risks identified in this model***
- ***Training crew members involved in vessel sailing regularly.***
- ***Inspiring crews for the efficient and responsible ship safety management.***
- ***Increasing the awareness of the importance of ship's safety.***

Conclusion

Conclusion

The paper provides comprehensive analysis of ship foundering risk factors using a three layers Hybrid Causal Logic model based on accident reports.

- The first layer of the model includes analyzing the risk probability of ship foundering accident using the ESD model.
- The second layer of the model uses FTA to analyze the Safety barrier represented non-human factors in the ESD model;
- The third layer of the model is the use of BBN in the analysis of human and organizational factors in the ESD model.
- Finally, the chains of events of ship foundering and the importance rankings of basic events can be obtained from the model, which provides theoretical guidance for policy makers and shipping companies regarding the prevention and control of ship foundering.

Thanks for your attention!

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