ISSN: 2664-9640

Summary of safety risk research methods in traffic intensive waters

Zhenzhen Ren

[1] Merchant Marine College, Shanghai Maritime University, Shanghai 201306, China;

[2] Department of Navigation Technology, Tianjin Maritime College, Tianjin 300350, China.

Abstract

Accidents occur frequently in water areas with dense traffic, and the traffic safety risk in water areas has become the research focus and difficulty in the field of water transportation. The paper summarizes the research methods of water traffic safety risk, and comment and prospected the research.

Keywords

Traffic intensive waters; Safety risk.

1. Introduction

With the continuous development of the water transportation industry, the transportation is becoming increasingly busy. A large number of ships are concentrated in ports, waterways and their adjacent waters, resulting in the increasing traffic density, the deteriorating ship navigation environment and the increasing water traffic risk[1].In September 18, 2020, a serious water traffic accident occurred on the old fellow rail road in the Bohai Strait. A merchant ship collided with a fishing boat, causing the fishing boat to sink. 10 of the crew members of the fishing boat were all missing. The direct economic loss was about 3 million yuan. Therefore, improving the safety and reliability of traffic intensive waters is an urgent need for the water transportation industry. The safety risk of traffic intensive waters has become the focus of shipping and academic circles.

2. Safety risk assessment method for traffic intensive waters

In order to scientifically measure the safety level of traffic intensive waters, many theories and models have been formed in this field. In 1992, the international organization put forward a risk assessment procedure, which is related to the international organization's "safety assessment". The current situation of safety research in traffic intensive waters can be summarized into the following parts:

2.1. Research on safety of traffic intensive waters based on accident data statistics

The analysis of historical accident data has been widely used in the research on the safety of transportation system in traffic intensive waters such as harbor[2], sea area[3][4], waterway [5].Typical research results include: Kujala conducted statistical analysis on maritime traffic safety in the Gulf of Finland and confirmed that grounding and collision are the main types of accidents in the Gulf of Finland. Through the statistical analysis of the historical congestion data of the Yangtze River, Zhang identified the key influencing factors of congestion and applied them to the analysis and prediction of the congestion risk of the Yangtze River[5]. Tirunagari conducted statistical analysis of multiple logistic regression model on ship accident data in Norwegian waters and determined the influencing factors related to navigation accidents[3].Wang proposed a comprehensive evaluation framework for quantifying collision

probability and collision consequences based on historical accident data in Hong Kong waters[4].

The development of statistical technology provides a powerful tool for the research on the safety of traffic intensive waters. Structural equation model (SEM) is a common statistical technology, which is used to determine the predictors that have a statistically significant impact on dependent variables. It has been preliminarily applied in the field of safety in traffic intensive waters. Chen used SEM statistical technology to evaluate the navigation safety of port waters[6] and port pilotage safety[7].Liu established the risk evolution index system of ship navigation environment in complex inland waters according to the principle of SEM[8].Hu used SEM algorithm to study the interaction and influence path of maritime traffic accident causes from the perspective of human factors [9]. Fenstad used SEM to explore the relationship between organizational and regulatory factors and ship safety[10].

2.2. Research on safety of traffic intensive waters based on uncertainty method

The method based on expert opinion has certain subjectivity and uncertainty. In order to solve this problem, fuzzy logic, belief network, Bayesian network, evidence reasoning and their combination have been greatly applied in water transportation risk assessment, including sea transportation risk[11-13], inland river transportation risk[14,15], port transportation risk[16] Navigation risks in Arctic waters[17], as well as specific navigation accident risks, such as collision risk[18], grounding risk[19], etc.

2.3. Research on safety of traffic intensive waters based on artificial intelligence method

The research of artificial intelligence in accident analysis of water transportation system is still limited. Similar studies include: Blanc used neural computing technology to analyze more than 900 marine accidents in the lower reaches of the Mississippi River[20].Erol analyzed the marine accidents in Istanbul Strait by using the combination of neuro fuzzy and genetic optimization fuzzy classifier, and believed that the solution to reduce the accident rate should give priority to weather conditions and ship density[21].Liu combined density based spatial clustering with noise technology and recurrent neural network, proposed a regional collision risk real-time prediction framework[22].

As one of the most popular artificial intelligence technologies, artificial neural network (ANN) modeling technology can identify complex nonlinear and non compensation relationships, and more accurately measure the relative impact of each predictor. In the field of safety in traffic intensive waters, Qiao determined the nonlinear factors related to human risk factors in Marine Accidents Based on ANN method[23]. Zissis used ANN method to predict ship behavior, including ship position, speed and heading[24]. Perera used ANN technology to detect and track multi-target ships[25].

2.4. Research on safety of traffic intensive waters based on simulation technology

Merrick evaluates the impact of ferry increase on the level of ship interaction in San Francisco Bay through interactive counting simulation[26].The simulation results show that the interaction between ferry and other ships increases exponentially rather than linearly with the number of ferry crossings. That means that the collision risk of ships in traffic intensive waters increases exponentially with the traffic density to a certain extent. Faghih-roohi proposed a maritime transportation accident risk model by using Markov model and Markov chain Monte Carlo simulation method[27].Chen used the simulation method of infectious disease dynamics to establish the risk causal model of ships sailing in traffic intensive waters, and modeled the key risk causal transmission process[28].

Zhang conducted simulation research on port pilotage risk by using system dynamics (SD) to clarify the impact of human and organizational factors on Pilotage accidents[29].The simulation

results show that the traffic intensive waters are very sensitive to human factors and organizational factors, and human errors will lead to a surge in accident probability. Zhang Yang combined with the risk evolution theory, used SD to simulate the risk evolution law of water transportation system[30].Liu conducted an in-depth study on the evolution process of ship navigation risk in the Three Gorges dam area using SD[31].Cao conducted coupling simulation on the causes of port navigation risk with the help of SD method from the perspective of port ship navigation complexity system[32].

To sum up, the current research on the safety of traffic intensive waters mainly focuses on the Straits, coastal ports and inland waterways[33]. For example, Merrick evaluated the impact of the increase of ferries on the collision risk of ships in the San Francisco Bay through interactive counting simulation, and confirmed its relationship with the exponential growth of the number of ferry crossings[26].Based on historical accident data, Zhang identified through Bayesian simulation that bad weather and narrow channel conditions are the key factors affecting the risk of traffic congestion in the Yangtze River[34].Zhang analyzed the temporal and spatial characteristics of ship traffic accidents in Singapore port waters based on the data of ship automatic identification system, and confirmed that ship speed is highly correlated with ship accidents[35].Jiang used the cusp catastrophe model to quantitatively evaluate the risk of navigation environment in the Three Gorges Reservoir area of the Yangtze River. The results show that the navigation environment from downstream to upstream is gradually deteriorating.

3. Research evaluation and Prospect

As the bearing area of huge traffic flow, traffic intensive waters play a vital role in the water transportation system. Providing safe and reliable transportation services and curbing frequent and persistent accidents is not only the primary task to be realized in traffic intensive waters, but also the common demand of the shipping industry and society. There is no doubt that the relevant research on the safety of traffic intensive waters has promoted the improvement of the safety level, but most of these documents focus on the overall safety evaluation of traffic intensive waters, and there is less analysis on the safety risks and causes of accidents in traffic intensive waters. Analyze the formation mechanism of safety risk in traffic intensive waters, build an objective and effective water traffic safety risk index system, reveal the evolution law of water traffic safety risk, and define the water traffic safety risk threshold, so as to provide theoretical basis and practical guidance for ensuring the safe, reliable, high-quality and efficient operation of traffic intensive waters. Specifically, the following key scientific problems need to be solved:

(1) How to understand the concept, meaning and formation mechanism of safety risk in traffic intensive waters? As a characteristic of water traffic safety, safety risk needs to further define the concept, clarify the specific meaning and elaborate the generation mechanism.

(2) How to build an objective and effective safety risk index system in traffic intensive waters? In the field of safety risk in traffic intensive waters, the water information is multidimensional, the influence relationship is complex, and the risk has the characteristics of concealment. Build an objective and effective risk index system, and quantitatively describe the importance of the index, so as to identify the weak links of water traffic safety from the Perspective of risk formation.

(3) How to quantitatively evaluate the evolution degree of safety risk in traffic intensive waters and identify key safety risks? There are many factors affecting the safety risk in traffic intensive waters, and the interaction relationship between the influencing factors is complex. The analysis of the safety risk evolution in traffic intensive waters and the identification of key safety risks are helpful to reveal the law of safety risk evolution and clarify the key points of risk monitoring.

References

[1] S.P.HU,C.H. HUANG,H. DENG, et al.Markov chain model for the dynamic simulation of process risk in ship pilotage at harbor,Journal of Harbin Engineering University. Vol. 38 (2017) No. 9, p. 1391-1398. (In Chinese)
[2] P.KUJALA, M.HAENNINEN, T.AROLA, et al. Analysis of the marine traffic safety in the Gulf of Finland,Reliability Engineering & System Safety, Vol. 94 (2009) No. 8, p. 1349-1357.
[3] S.TIRUNAGARI, M.HANNINEN, K.STANHLBERG, et al. Mining Causal Relations and Concepts in Maritime Accidents Investigation Reports, International Journal of Innovative Research and Development, Vol. 1 (2017) No.10, p. 548-566.
[4] Y.WANG, L.WANG, J.JIANG, et al. Modelling ship collision risk based on the statistical analysis of historical data: A case study in Hong Kong waters, Ocean Engineering, Vol. 197 (2020), p. 1-12.
[5] D.ZHANG, X.YAN, Z.YANG, et al. An accident data–based approach for congestion risk assessment of inland waterways: A Yangtze River case, Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, Vol. 228 (2014) No. 2, p. 176-188.
[6] H.W.CHEN. Evaluation of Navigation Safety in the Port Water Area Based on SEM(MS., Wuhan University of Technology, China 2012).
[7] H.CHEN, H.WANG. Analysis of the port sailing safety based on SEM, International Conference on Consumer Electronics, Vol. 26 (2014): 160-163.
[8] Q.LIU, P.QIN, S.LI, et al. Research on inland river complex waters navigation environment risk evolution index system, China Safety Science Journal, Vol. 24 (2014) No. 8, p. 139-144. (In Chinese)
[9] S.HU, Z.LI, Y.XI, et al. Path Analysis of Causal Factors Influencing Marine Traffic Accident via Structural Equation Numerical Modeling, Journal of Marine Science and Engineering,
Vol. 7 (2019) No.4, p. 96-115.
[10] J.FENSTAD, Ø.DAHL, T.KONGSVIK. Shipboard safety: exploring organizational and regulatory factors, Maritime Policy & Management, Vol. 43 (2016) No. 5, p. 552-568.
[11] P.TRUCCO, E.CAGNO, F.RUGGERI, et al. A Bayesian Belief Network modelling of organisational factors in risk analysis: A case study in maritime transportation, Reliability Engineering & System Safety, Vol. 93 (2008) No. 6, p. 845-856.
[12] G.ZHANG, V.V.THAI, K.F.YUEN, et al. Addressing the epistemic uncertainty in maritime accidents modelling using Bayesian network with interval probabilities, Safety Science, Vol. 102 (2018), p. 211-225.
[13] J.W.MERRICK, J.R. VAN, V.DINESH. Assessing uncertainty in simulation-based maritime risk assessment, Risk Analysis, Vol. 25 (2005) No.3, p. 731-743.
[14] D.ZHANG, X.P.YAN, Z.L.YANG, et al. Incorporation of formal safety assessment and Bayesian network in navigational risk estimation of the Yangtze River, Reliability Engineering & System Safety, Vol. 118 (2013) No. 10, p. 93-105.
[15] D.ZHANG, X.YAN, J.ZHANG, et al. Use of fuzzy rule-based evidential reasoning approach in the navigational risk assessment of inland waterway transportation systems, Safety Science, Vol. 82 (2016), p. 352-360.
[16] J .ZHANG, Â. P. TEIXEIRA, C. G. SOARES, et al. Maritime Transportation Risk Assessment of Tianjin Port with Bayesian Belief Networks, Risk Analysis, Vol. 36 (2016) No. 6, p. 1171-1181.
[17] B .AL-AMIN, R .ABBASSI, G .VIKRAM, et al. Marine transportation risk assessment using Bayesian Network: Application to Arctic waters, Ocean Engineering, Vol. 159 (2018), p. 422-436.
[18] B .LI, F .PANG. An approach of vessel collision risk assessment based on the D–S evidence theory, Ocean Engineering, Vol. 74 (2013), p. 16-21.
[19] A .MAZAHERI, J .MONTEWKA, P .KUJALA. Towards an evidence-based probabilistic risk model for ship-grounding accidents, Safety Science, Vol. 86 (2016), p. 195-210.
[20] L. L. BLANC, R. R. HASHEMI, C. T. RUCKS. Pattern development for vessel accidents: a comparison of statistical and neural computing techniques, Expert Systems With Applications, Vol. 20 (2001) No.2, p. 163-171.
[21] S .EROL, M .DEMIR, B .CETISLI, et al. Analysis of ship accidents in the Istanbul Strait using neuro-fuzzy and genetically optimised fuzzy classifiers, Journal of Navigation, Vol. 71 (2017) No. 2, p. 419-436.

[22] D. P. LIU, W .XIN, C .YAO, et al. A Novel Framework of Real-Time Regional Collision Risk Prediction Based on the RNN Approach, Journal of Marine Science and Engineering, Vol. 8 (2020) No. 3, p. 1-19.
[23] W .QIAO, Y .LIU, X .MA, et al. A methodology to evaluate human factors contributed to maritime accident by mapping fuzzy FT into ANN based on HFACS, Ocean Engineering, Vol. 197(2020), p. 1-8.
[24] D .ZISSIS, E .K. XIDIAS, D .LEKKAS. A cloud based architecture capable of perceiving and predicting multiple vessel behaviour, Applied Soft Computing, Vol. 35 (2015), p. 652-661.
[25] L .P. PERERA, P .OLIVEIRA, C. G. SOARES. Maritime Traffic Monitoring Based on Vessel Detection, Tracking, State Estimation, and Trajectory Prediction, IEEE Transactions on Intelligent Transportation Systems, Vol. 13 (2012) No. 3, p. 1188-1200.
[26] J .W .MERRICK, J .R. VAN, J .P. BLACKFORD, et al. A traffic density analysis of proposed ferry service expansion in San Francisco Bay using a maritime simulation model, Reliability Engineering & System Safety, Vol. 81 (2003) No. 2, p. 119-132.
[27] S .FAGHIH-ROOHI, M .XIE, K.M. NG. Accident risk assessment in marine transportation via Markov modelling and Markov Chain Monte Carlo simulation, Ocean Engineering, Vol. 91(2014) No. 15, p. 363-370.
[28] Y .CHEN, Q .LIU, C .WAN. Risk causal analysis of traffic-intensive waters based on infectious disease dynamics, Journal of Marine Science and Engineering, Vol. 7 (2019) No. 8, p. 277-295.
[29] X .ZHANG, W .CHEN, Y .XI, et al. Dynamics Simulation of the Risk Coupling Effect between Maritime Pilotage Human Factors under the HFACS Framework, Journal of Marine Science and Engineering, Vol. 8 (2020) No.2, p. 144-162.
[30] Y .ZHANG, Y .T. XI, S. P. HU, et al. System dynamics simulation on risk evolution of cargo transportation on water, Journal of Shanghai Maritime University, Vol. 39 (2018) No. 1, p. 19-24.
[31] Q .LIU, D .D. HAN, Y .Q. CHEN, et al. Research on navigation risk evolution in Three Gorges dam area based on system dynamics, China Safety Science Journal, Vol. 26 (2016) No. 4, p. 19-23. (In Chinese)
[32] J .H. CAO, Y .T. XI, S .P. HU, et al. Coupling model for risk formation on ship navigation at port water areas using system dynamics, Journal of Safety and Environment, Vol. 15 (2015) No. 3, p. 65-71. (In Chinese)
[33] Y .J. CHEN, Q .LIU, C .P. WAN, et al. Brittle nodes identification of navigation system in traffic flow intensive waters in emergency situations, Journal of South China University of Technology (Natural Science Edition), Vol. 47 (2019) No. 11, p. 54-70. (In Chinese)
[34] D .ZHANG, X .YAN, Z .YANG, et al. An accident data-based approach for congestion risk assessment of inland waterways: A Yangtze River case, Proceedings of the Institution of Mechanical Engineers Part O Journal of Risk & Reliability, Vol. 228 (2014) No. 2, p. 176-188.
[35] L .ZHANG, Q .MENG, T. F. FWA. Big AIS data based spatial-temporal analyses of ship traffic in Singapore port waters, Transportation Research Part E-logistics and Transportation Review, Vol. 129 (2017), p. 287-304.