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Safety Analysis of Risk Factors in Developing Arctic Shipping Routes

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Abstract

With the global warming, the Arctic ice layer has receded, and the navigation environment in the Arctic has been improved to a certain extent. As a transportation shortcut linking the economically active regions of Asia and Europe and an important global energy source, the realization of Arctic navigation will definitely change the world's shipping pattern. As an important stakeholder in Arctic affairs, the development of Arctic routes will also bring great economic, political and strategic value to the expansion of global development space in the next 30-50 years. However, the navigation safety of this "golden channel" is still a major problem facing its development and utilization. Due to the special geographical location, extreme weather and "public land" attributes, the safety of Arctic navigation is far more prominent than general maritime transportation channels. This article uses statistical analysis of Arctic maritime accident data to find out the risk factors of accidents, and uses contingency table and chi-square test to analyze the correlation between each risk factor and the severity of Arctic maritime accidents. Studies have shown that, unlike traditional routes, the main risk factors are visibility and wind conditions. Air temperature, a factor that is not often considered as a risk in traditional routes, is significantly related to Arctic maritime accidents. Low temperature causes chain reactions (such as equipment downtime, personnel slow activity) has affected the occurrence of maritime accidents in the Arctic. Second, the polar day and night phenomenon in the Arctic has an impact on the accident to a certain extent. Sea conditions (including waves, swells, and ice), as the external environment directly contacted by ships during navigation, are closely related to the severity of the accident, which is also supported by data on Arctic routes. The conclusions of this paper can provide scientific decision-making for the safety of ships on Arctic routes and provide support for effective navigation to reduce risks.

Keywords

Arctic route; Safety; SPSS.

1. INTRODUCTION

With the global warming, the ice in the Arctic is gradually melting, and the Arctic Ocean has revealed its potential as a new commercial shipping route0. Compared with traditional routes, the Arctic route can greatly shorten the sailing distance, thereby shortening the sailing time, saving operating costs, and achieving higher economic benefits[2]-[4].

The Arctic Passage is usually divided into Northwest Passage (NWP), Northeast Passage (NEP), and the passage through the North Pole. Generally, the Northwest Passage refers to the pass from Greenland to the northern coast of Alaska via the Arctic Islands in northern Canada. The Northeast Passage refers to the Bering Strait as its starting point, passing through the Arctic

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Ocean Chukchi Sea, Novosibirsk Sea, Laptev Sea, Kara Sea and Barents Sea in order to the west until northern Europe. The route through the North Pole refers to the Bering Strait as a starting point, passing directly through the North Pole to the Greenland Sea or the Norwegian Sea, and the whole journey is about 2,700 nautical miles. Since the North Pole area is covered by sea ice accumulated over many years, the sea ice is the densest and thickest, this route will be the last to be developed and utilized.

At present, the Arctic waterway has become the focus of research and development in various countries and has strong economic attractiveness[5]. The main reasons is that it has abundant strategically significant and developable resources. The second is that the rapid reduction of sea ice in the Arctic has increased the possibility of navigation. This channel is a shortcut between the three most developed industrialized continents in the world. According to the study of cargo flows on Arctic routes, it can be found that oil cargo flows account for a large proportion in the last 10 to 20 years [6]-[8]. In recent years, China's rapid development has increased its demand for oil. However, due to the political sensitivity of the traditional routes through the Strait of Malacca, the Panama Canal, the waters of Somalia and the Suez Canal, the risk of piracy is high. Opening up a new oil import route, the Arctic route is of great significance to China.

However, the special environment of the Arctic region brings many uncertainties to the feasibility of navigation[9]. For example, the existence of ice floes requires ships sailing in the Arctic to have a certain icebreaking ability or need to hire icebreakers to open the road ahead; low temperature in the polar regions, extreme day and night , poor navigation signals and other phenomena may affect the crew's driving behavior and increase navigation risks; the ecological fragility of the Arctic places environmental protection requirements on the type of fuel used by ships and navigational emissions [8]. This is the necessity for this article to start the discussion on the safety of development of Arctic routes.

2. ANALYSIS OF RISK FACTORS

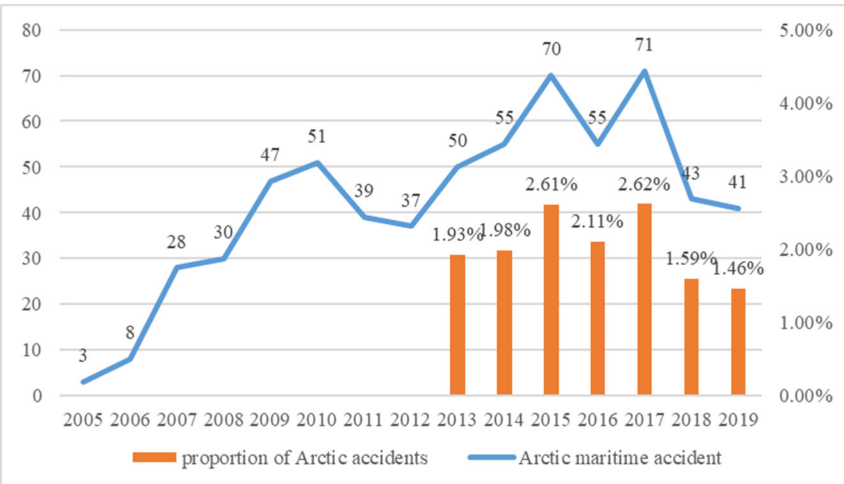

Figure 1. Statistics of Arctic Maritime Accidents (2005-2019)

Source: Safety and Shipping Review published by AGCS (reports from 2014 to 2019)

According to the report of ALLIANZ GLOBAL CORPORATE & SPECIALTY (AGCS): Since 2005, the overall Arctic maritime accidents have been on the rise; accounting for about 2% of the total global maritime accidents, as shown in Figure 1. Compared with the traditional Eurasian waterway, the Arctic waterway is located in the Arctic waters. Ships can avoid the seas of Southeast Asia and the Gulf of Aden where pirates are rampant, and bypass the political and economically sensitive Persian Gulf. But at the same time, the special location of the Arctic waters also brings special risks to the navigation of ships. For example, the cold environment of the Arctic has high requirements for the anti-freezing ability of ship equipment and facilities, which may affect the use of equipment and cause accidents; the signal coverage and connectivity problems in the polar regions may affect the ship's reception of land information, which cannot be obtained in danger Rescue: There are a lot of ice floes in the Arctic waters, which may be different from the surge conditions that also exist in traditional routes, and become a new factor affecting ship navigation.

3. ACCIDENT DATA ANALYSIS

Table 1. Statistics of maritime accidents in the Arctic

Variable		Category	Percentage
Consequences of the accident	Severity	Not Severe	28.3%
		Severe	71.7%
Accident Information	Season	Summer (May- October)	95.3%
		Winter (January -April & November – December)	4.7%
	Type	Grounding	30.2%
		Collision	18.9%
		Machine damage/Ship damage	24.5%
		ship capsize	6.6%
		Fire	5.7%
		Others	14.1%
	Accident area	Sea Area	26.4%
		Restricted Water Area (Including the port area)	52.8%
		Other Water Area	20.8%
	Rescue situation	No	71.7%
		Yes	28.3%
Meteorological environment	visibility Light condition	Good (>5 n mile)	67.9%
		Bad (<5n mile)	32.1%
	Wind Sea Condition	Day	65.1%
		Night	25.5%
		Hazy	9.4%
	visibility Light condition	Good	97.2%
		Bad	2.8%
	Wind Sea Condition	Good	69.8%
		Bad	30.2%
	Temperature	Good	11.3%
		Bad	88.7%

In order to explore the risk factors that affect the safety of ships' Arctic navigation in more detail, this article intends to collect accident information details from the relevant statistical agencies of the two main countries along the Arctic route, Russia and Canada. However, because Russia did not disclose the corresponding detailed accidents, this article finally retrieved and collected Arctic maritime accident data from the public database of the Transportation Safety Board of Canada (TSB) from 2000 to 2019, a total of 133 pieces of data. The items with severely missing data were eliminated, and a total of 106 pieces of accident data were retained for risk analysis.

The statistics of Arctic maritime accident data are shown in Table 1. It can be found that Arctic maritime accidents have the following basic characteristics: (1) The severity of maritime accidents is determined based on the standard of ship damage. It can be found that the severity of Arctic maritime accidents is relatively high. Two-thirds of Arctic maritime accidents will cause ship damage. (2) Arctic maritime accidents mostly occur in summer. This is due to the melting of Arctic sea ice in summer forming a window of time for navigation. Most ships only start Arctic sailing during this period; (3) The types of maritime accidents on Arctic routes are mostly grounding, machine damage/ship damage, collision/contact, respectively, which are 30.2%, 24.5%, and 18.9%; (4) With the same reason that ships usually sail in summer, most maritime accidents in the Arctic are in good wind conditions. In the Arctic summer, the wind is relatively small, with an average wind speed of 4-6 m/s.

4. CHI-SQUARE TEST

Based on the above-mentioned 106 Arctic maritime accident data, the contingency table and chi-square test are used to analyze the correlation between various risk factors and the severity of Arctic maritime accidents. by using SPSS software, the correlation between accident severity and basic accident information variables calculated is shown in Table 2, the correlation between accident severity and meteorological environment variables is shown in Table 3; the significant correlation between accident severity and each variable is shown in Table 4.

Table 2. Correlation between accident severity and basic accident information variables

Accident Severity		Season		Type of accident						Accident area			Rescue situation	
		Summer	Winter	Grounding	Collision	Machine damage/Ship damage	ship capsize	Fire	Others	Sea Area	Restricted Water Area	Other Water Area	No	Yes
Not Severe	Frequency	29	1	13	5	2	0	1	9	9	18	3	30	0
	Percentage	96.75%	3.3%	43.3%	16.7%	6.7%	0%	3.3%	30%	30%	60%	10%	100%	0%
Severe	Frequency	72	4	19	15	24	7	5	6	19	38	19	46	30
	Percentage	94.7%	5.3%	25.0%	19.7%	31.6%	9.2%	6.6%	7.9%	25%	50%	25%	60.5%	39.5%

Table 3. Correlation between accident severity and meteorological environment variables

Accident Severity		Visibility		Light condition			Wind		Sea Condition		Temperature	
		Good	Bad	Day	Night	Hazy	Good	Bad	Good	Bad	Good	Bad
Not Severe	Frequency	19	11	17	7	6	30	0	26	4	9	21
	Percentage	63.3%	36.7%	56.7%	23.3%	20.0%	100%	0%	86.7%	13.3%	30.0%	70.0%
Severe	Frequency	53	23	52	20	4	73	3	48	28	3	73
	Percentage	69.7%	30.3%	68.4%	26.3%	5.3%	96.1%	3.9%	63.2%	36.8%	3.9%	96.1%

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Tab 4. Significant correlation between accident severity and each variable

Variable		Pearson's Chi-Square Value	Degrees of Freedom	Asymptotic Significance (two-sided)
Accident Information	Season	0.178	1	0.673
	Type of accident	18.535	5	0.002**
	Accident area	2.943	2	0.230
	Rescue situation	16.517	1	0.000**
Weather Environment	visibility	0.405	1	0.525
	Light condition	5.483	2	0.064*
	Wind	1.219	1	0.270
	Sea Condition	5.641	1	0.018**
	Temperature	14.542	1	0.000**

Note: ** indicates that the corresponding variable is significant at a 95% confidence level, and * indicates that the corresponding variable is significant at a 90% confidence level.

5. DISCUSSION

In terms of basic accident information, combining Table 2 and Table 4, the following findings can be obtained. First of all, since most ships will choose to sail in the Arctic waters in summer, the seasonal distribution of accident data will inevitably lean towards summer. Therefore, the relationship between accident season and accident severity cannot be well explained. However, there is a significant relationship between the main types of accidents that occur in the Arctic waters and the severity of the accident. Among them, aircraft damage/ship damage, grounding, collision/touch are the main types of Arctic maritime accidents. In traditional routes, collisions and groundings are the most common types of accidents, while in the Arctic routes, the proportion of ship/machine damage and has increased significantly because of the cold Arctic weather and the existence of floating ice, which also increase the possibility of ship equipment failure and hull scratches. In addition, due to signal restrictions and thicker sea ice in the Arctic Ocean, most ships sailing in the Arctic will travel along the coast as much as possible. If the ship has a deep draft, it may increase the risk of grounding. This also shows from another side that most ships sailing in Arctic waters are sailing in restricted waters, and there is little difference between ships sailing in areas with sea ice and in restricted waters (limited in depth and width of channel). Therefore, "restricted waters", a risk factor that is more prominent in traditional routes, has little relevance to the accidents on Arctic routes. Secondly, if a ship is in danger during the Arctic voyage, timely rescue is essential. The data shows that there is a significant relationship between the rescue situation and the severity of the accident. Among serious accidents, the proportion of accidents that are not rescued accounted for 60.5%. Therefore, when sailing on the Arctic route, ships should ensure that they maintain real-time contact with the land as much as possible, and call for help as soon as possible when a dangerous situation is discovered. In addition, the "Arctic Sea and Air Search and Rescue Cooperation Agreement" promulgated by the Arctic Council should be fully implemented to maintain the safety of Arctic navigation.

At the level of meteorological environment, the difference in risk factors between Arctic routes and traditional routes is more obvious. Combining Table 3 and Table 4, first of all, visibility and wind conditions are generally recognized risk factors in traditional routes, but in Arctic waters, they have no significant correlation with maritime accidents. However, temperature is not often considered a risk on traditional shipping routes, was significantly associated with Arctic maritime accidents. This shows that visibility and wind conditions are not the main causes of maritime accidents in the Arctic, but the chain reaction (such as

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equipment downtime and slower activities) caused by low temperature has more impact on the occurrence of maritime accidents in the Arctic. Second, the polar day and night phenomenon in the Arctic has an impact on the accident to a certain extent. However, sea conditions (including waves, swells, and ice), as the external environment directly contacted by ships during navigation, are bound to be related to the severity of the accident. This is supported by data on the Arctic route.

6. CONCLUSION

Through the analysis of the Arctic maritime accident data, it can be found that the special environment of the Arctic waters has made special requirements for ship navigation. In order to ensure the safety of ship navigation, relevant parties should focus on the special risk factors of the Arctic, such as extreme day and night, sea ice, temperature, etc., so as to maintain communication with ships and provide timely rescue.

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