JOURNAL OF MARITIME RESEARCH

Vol XX. No. I (2023) pp 165–174

ISSN: 1697-4040, www.jmr.unican.es

Inland Waterway Transport Accident Analysis of Bangladesh: Based on Location, Time, and Regression Approach

Ahammad Abdullah[1], Md. Jobayer Mia[2,*], Mohammad Rasel khan[3], Md. Imran Uddin[4], Utpal K. Dhar[5]

ARTICLE INFO

Article history:
Received 21 Jan 2023;
in revised from 25 Mar 2023;
accepted 10 Apr 2023.

Keywords:
Inland waterway accident, Inland waterway, Regression Analysis, Casualties, Bangladesh.

ABSTRACT

Riverine Bangladesh, situated in the foothills of the Himalayas within the South Asian continent, boasts an extensive network of waterways. These water bodies encompass various features, including small hill ranges, meandering seasonal creeks, canals, picturesque rivers, and numerous tributaries. Numerous cities and ports have been established on both sides of these rivers. These waterways are intricately woven into the fabric of the country's civilization and agricultural system, serving as a vital mode of communication and cost-effective transportation for goods. In this context, it is important to acknowledge that waterway accidents have long been a recurring issue in Bangladesh. Many individuals suffer injuries, and fatalities, or go missing each year due to maritime accidents. When a major maritime accident occurs, there is a temporary outcry, and both the media and concerned authorities conduct brief investigations. However, this research delves into the analysis of accident data from 1995 to 2019, aiming to identify the key factors contributing to accidents by applying multiple linear regression theory in various mathematical configurations. The model's validity has been affirmed through the utilization of diverse datasets. Furthermore, the study unveils accident-prone regions and presents a time-based breakdown of accident occurrences, offering a comprehensive understanding of accident patterns. The insights garnered from this study can potentially guide stakeholders and relevant authorities in making informed decisions to proactively mitigate waterway accidents. Finally, this study offers recommendations for reducing the number of accident path planning and accident avoidance and a theoretical foundation for driver assistance systems.

1. Introduction.

Bangladesh has approximately 700 interconnecting rivers, along with their tributaries, gracefully traverse the expanse of the nation, covering an expansive 24,140 square kilometers brimming with substantial water reserves. This intricate network of water bodies blankets nearly 7% of Bangladesh's total land area. In terms of aquatic domains, Bangladesh's jurisdiction extends over around 9,000 square kilometers of territorial waters, harmonizing with an extensive 7,200-kilometer coastline (Banglapedia, 2021).

The navigable stretches of inland waterways span approximately 5,968 kilometers, a distance that contracts to 3,600 kilometers during the dryer seasons (BIWTA, 2021). These inland water routes have been thoughtfully categorized into four distinct classes, their classification contingent on traffic volume and economic importance (BIWTA, 2021).

As outlined in the forward-looking 'Delta Plan-2100' crafted by the Bangladeshi government, the river transport system stands as a fundamental conduit for fostering economic progress and

[1]Department of Ocean & Mechanical Engineering, Florida Atlantic University, USA.

[2]Department of Naval Architecture and Offshore Engineering, Bangabandhu Sheikh Mujibur Rahman Maritime University, Bangladesh.

[3]Department of Naval Architecture and Marine Engineering, Bangladesh University of Engineering and Technology, Dhaka.

[4]Accident Research Institute, Bangladesh University of Engineering and Technology, Dhaka.

[5]Department of Ocean & Mechanical Engineering, Florida Atlantic University, USA.

*Corresponding author: Md. Jobayer Mia. E-mail Address: jobayer.naoe@bsmrmu.edu.bd.

overall development. Moreover, the waterway transportation framework demonstrates an extensive reach, seamlessly integrated into the wider transportation network. An increasing reliance on this river transport infrastructure is observed, with a substantial number?roughly 50,000 individuals?utilizing inland waterways for both personal travel and the movement of goods, particularly in the southern regions of the country. Remarkably, over 50% of the country's total merchandise and a quarter of the entire passenger volume are efficiently conveyed through the medium of inland water transport, as highlighted by the Bangladesh Inland Water Transport Authority (BIWTA, 2021).

As indicated by Akhter (2017), a staggering 5,407 lives have been lost in 600 maritime incidents spanning the past four decades. Tragically, the mortality toll is not showing signs of decline; in fact, it's distressingly on the rise. Recent years have witnessed a distressing surge in fatalities, surpassing previous records. Nevertheless, the 'Inland Shipping Ordinance-1976,' is designed to regulate and secure navigation. This ordinance comprehensively addresses shipping and transport regulations, along with corresponding penalties for those who flout them. Astonishingly, this critical knowledge seems to elude drivers, vehicle owners, and passengers alike, leading to a recurring cycle of accidents prompted by the reckless actions of these parties.

The spectrum of accidents is diverse and rooted in numerous causes, including exceeding cargo or passenger limits, drivers' negligence and incompetence, faulty vehicle components, adverse weather conditions, substandard vehicle structures, perilous sea routes, expired vehicle fitness certifications, ship collisions, unlicensed operators, radar or radio equipment inadequacies, overpowering currents, inadequate monitoring or control systems, lack of strict punitive measures, deficient supervision, overloading, natural calamities, and a general lack of awareness.

The primary objective of this study is to delve into the factors contributing to inland waterway accidents in Bangladesh, employing a multifaceted analysis approach encompassing geographical and temporal considerations. Additionally, a novel strategy involving regression analysis is introduced to anticipate accident numbers. This research delves into identifying the pivotal causes, treated as independent variables, that escalate the response variable, namely the frequency/number of accidents. By pinpointing the core triggers behind these accidents, the study proposes actionable recommendations to the maritime authority. These propositions aim to enhance inland waterway safety in Bangladesh, ultimately curbing the unfortunate toll of casualties.

2. Review of Existing Literature.

As told by the Directorate of Maritime Transport of the Government of Bangladesh, there were 608 boat accidents in Bangladesh from 1991 to 2018, and sadly, 3 thousand people lost their lives. Among them, 1,781 were passengers on launches (Bdnews24, 2019). Another report from a private organization called the National Committee for the Protection of Sea, Road, and Railway revealed that there were 653 accidents involving both small and big launches in the 20 years from 1996 to 2015. These accidents led to a total of 6,408 casualties (Haque, 2017).

On a different note, the river situation tells us something else. A safety-focused group called Nogar shared that between 2005 and 2019, more than 6,000 people lost their lives in 535 big accidents on the water. They made 863 groups to look into these accidents (Bengali Tribune, 2019). But very few of these groups' findings have been made public. While studying this, we found that many research studies focus on water accidents as separate incidents and blame safety authorities. They don't see the issue as a bigger problem in the system. These studies lack detailed looks into the accidents and why they happen (causal factors).

Khalil and Tarafder (2004) studied ferry disasters in the rivers of Bangladesh and suggested some modifications in vessel design for the acquisition of additional initial stability due to an upward change in the center of gravity to keep the vessel safe from capsizing. Baten (2005) discussed irregularities in the maritime transportation sector from a safety viewpoint and criticized the current rules of the Inland Shipping Ordinance (ISO 1976) for being inept and recommended specific reforms of the rules. Chowdhury (2005) devolved a GIS-based accident information system for analyzing maritime accidents. Huq and Dewan (2006) suggested to ensure radar and radio equipment?s in all types of passenger vessels. The study also recommended to establish efficient marine court to ensure the passenger safety.Awal et al (2007) found that relatively higher percentage of maritime accidents occur during the monsoon period due to adverse weather. The study also showed that accident rate is slightly higher during business hours. The study recommended to improve the weather forecasting system of Bangladesh. Iqbal et al. (2008) proposed to ensure additional above water reserve buoyancy in small vessels. The study suggested modifying the weather criterion considering wind speed, rolling of thevessels, and crowding of people on one particular side of the vessel.

A study by Azad (2009) found the primary reasons behind maritime accidents are-recruitment of unskilled masters and crews, relevant government bodies are understaffed, and maintenance of the vessels are low quality. Rahman and Rosli (2014) developed a model to detect overloading in inland vessels by using the elevator concept. The author also discussed the necessity of implementing overloading detection systems in inland vessels. Stornes (2015) utilized multinomial regression to analyze and explain the differences in accidents. The study found that accident types had only slight variations across different vessel types, gross tonnages, and lengths. However, the variations in accident types were significantly more pronounced when considering different bodies of water.In a study conducted by Zhao and Lv (2016), a comparison was made among various predictionapproaches for maritime accidents. The researchers characterized regression analysis as a statistical tool employed to comprehend the connection between a main variable and several supporting variables. Within the realm of maritime accidents, the authors recommended that regression analysis could play a pivotal role in pinpointing and evaluating the elements that influence the emergence and intensity of searelated incidents.

Uddin et al (2017) analyzed inland waterway accidents that occurred from 2005 to 2015 and found that almost two-thirds of the accidents happened due to collisions between two vessels and 45% of the vessels sunk after the accidents. The study is recommended to ensure proper investigation of accidents and to create mass awareness among the people. Rahman (2017) analyzed maritime accidents that occurred from 1981 to 2015 and found that the rate of accidents has increased dramatically in recent years. The study proposed that every vessel must have sufficient navigational visibility to avoid collision during foggy weather. The study also suggested that all passenger vessels should have a common structural design approved by the Department of shipping. Probha (2017) conducted a comparative analysis of passenger safety in highways, railways, and waterways and found that waterway accidents contributed a significant percentage (about 37%) of the total accidents from 2008 to 2015.

In another study conducted by Wang et al. (2019), a comprehensive examination was carried out on collision accidents, with a specific emphasis on human-related factors. The researchers took a closer look at the precise factors contributing to collisions and utilized Logistic analysis to pinpoint the most prominent influences. Their investigation delved into the intricacies of ship collisions using Logistic Ordered Multiple Regression, a component of Regression Analysis, to gain a more profound understanding of the underlying causes (Wang et al., 2019).Mia et al. (2021) analyzed the characteristics of maritime accidents that occurred during the last 25 years and found that collision is the main reason for waterway accidents in Bangladesh. This study also performed a distinctive analysis of maritime accidents that occurred from 2010 to 2019 and showed that the rate of accidents has increased by 7.5% in recent years but the death rate has decreased by 23.2

In the scope of this study, the authors have embarked on a different approach to resolve the factors contributing to inland waterway accidents in Bangladesh. This methodology diverges significantly from the aforementioned analytical methods commonly employed in accident research. The authors' innovative strategy involves employing a mathematical model not only to elucidate the causes of accidents but also to gauge their intensity. To this end, an array of distinct parameters, including collision instances, stormy weather, and excessive currents, among others, are considered independent variables. These variablesare juxtaposed against the outcome variable, or the number of accidents, also known as the response variable. This method not only furnishes a novel perspective but also lays the groundwork for formulating a comprehensive mathematical model capable of predicting accident numbers on a broader scale.

3. Data Collection.

The primary objective of this research endeavor is to uncover the underlying factors contributing to the series of maritime accidents that have taken place in Bangladesh over the last quarter-century. This exploration is approached through the utilization of regression analysis. Throughout the study, the most challenging aspect proved to be the acquisition of accurate and credible data, which subsequently had to be meticulously organized in a suitable way. The task was further compounded by the absence of comprehensive and detailed information, adding to the complexity of the undertaking. The utmost priority was sourcing data from reliable sources, with our main focus directed toward institutions like the Department of Shipping (DOS) and the Bangladesh Inland Water Transport Authority (BIWTA). Additionally, data was sourced from the Accident Research Institute (ARI) at Bangladesh University of Engineering Technology (BUET), along with reputable daily newspapers within Bangladesh. Notably, it was observed that DOS and BIWTA primarily gather data for legal purposes, thus rendering the process of assembling data for scientific analysis notably intricate. Daily newspapers, on the other hand, tend to emphasize subjective elements, typically neglecting the inclusion of technical parameters in their reports.

Developing the database proved to be an intricate and time-intensive process; nonetheless, it was essential to have a reliable database to substantiate our work. A relevant precedent set by Mia et al. in 2020 was employed as a reference for database development, similar to what was undertaken for this study. Our approach involved a comprehensive examination of accident locations and times to gain a profound understanding of the subject matter. We then identified the primary factors contributing to these accidents, which were subsequently used as variables in our regression analysis. After thorough consideration, these factors were categorized into six distinct groups. All maritime accidents that transpired between 1995 and 2019 were included in our analysis. For the execution of the regression analysis, we employed tools such as Microsoft Excel and Minitab: Data Analysis, Statistical & Process Improvement Tools. To visually present the findings, graphical representations were generated using Matlab and ArcGIS. Special attention was given to ensure that the presentation of the results remained both transparent and unequivocal.

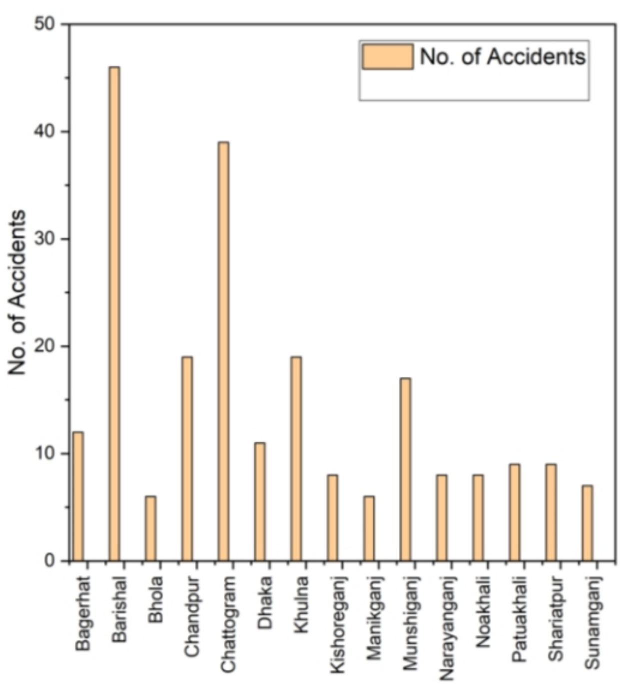
4. Methodology.

Utilizing the compiled data, this research unfolds through three distinct approaches that meticulously scrutinize the factors behind accidents, offering a more refined analysis compared to the previously discussed method. Firstly, a location-based examination is undertaken, proving to be remarkably effective in pinpointing accident-prone zones by sorting through the highest frequency of accidents. Secondly, an analysis centered around the timing of accidents is conducted. This method unveils specific timeframes when accidents have peaked, providing valuable insights. Lastly, a regression analysis is employed to forecast the number of accidents attributed to various causes directly linked to the occurrence of these incidents. In this regression analysis, the predicted accident count serves as the dependent variable, while the causes of accidents act as independent variables.

5. District Wise Distribution of Accidents.

Through a comprehensive examination of waterway routes and their associated accidents, the uncovered results are undeniably alarming. As depicted in Figure 1, a noticeable correlation emerges between the frequency of accidents and the density of vessels operating along specific river routes. Notably, the routes of Barishal and Chattogram emerge as the most bustling hubs of water transportation in Bangladesh. Regrettably, these two routes have also borne the brunt of the highest number of accidents over the past two decades. Expanding our view, it becomes apparent that districts like Dhaka, Narayanganj, Chandpur, Khulna, and Munshiganj are particularly susceptible to accidents, making them the regions with the highest incidents in Bangladesh. This pattern extends to a total of 26 districts that have encountered at least one water transport accident within the last 25 years. This coverage essentially spans across nearly all significant riverways of Bangladesh, highlighting the widespread nature of this issue.

Figure 1: Location-wise distribution of waterway accidents.

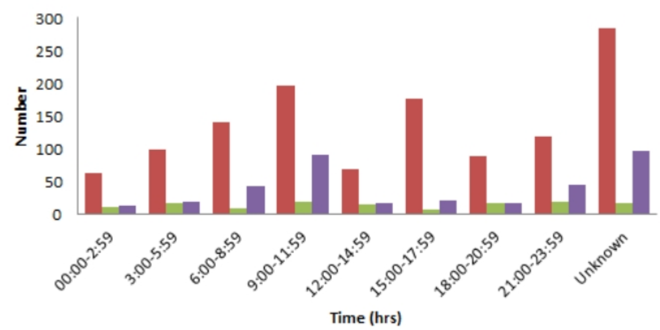


Source: Authors.

6. Hourly Distribution of Accidents.

Approximately two-thirds of the incidents transpiring on Bangladesh's water routes stem from collisions between two watercraft. This prevalent issue primarily arises during nighttime hours or when fog blankets the surroundings in winter, impeding visibility (Uddin et al., 2017). A depiction in Figure 2 delineates the distribution of accidents throughout the day. Accidents are a recurring phenomenon throughout the entirety of the day. The visualization further underscores a higher frequency of accidents in the afternoon and evening (Post Meridiem or PM) compared to the morning hours (Ante Meridiem or AM). Notably, a concerning spike in accidents manifests between 10 AM and 4 PM, a period bustling with business activities and the movement of numerous passengers and professionals via waterways. Another noteworthy observation pertains to a substantial cluster of accidents between 6 PM and midnight. This occurrence can be attributed to the inadequate navigational and lighting amenities on a significant portion of Bangladeshi vessels (Mia et al., 2020).

Figure 2: Timewise distribution of waterway accidents.



Source: Authors.

Media outlets frequently highlight incidents involving submerged vessels, collisions between immobile vessels and others in operation, as well as the inadequate presence of effective navigational aids along water routes. It is recommended that vessels incorporate essential equipment such as radar for navigation guidance, GPS systems, echo sounders to measure riverbed depth, fog lights for improved visibility during foggy conditions, high-power VHF radios for seamless ship-to-ship communication, and electric wheels to regulate ship speed. Despite the operation of 695 passenger ships across the nation, nearly half of them are deficient in these critical tools. Among the 70 luxurious launches, ten are suitably equipped for safe navigation during dense fog (Mostofa, 2021). This discrepancy poses substantial risks to vessels operating at night, potentially leading to accidents. Unfortunately, the timing of a significant portion of these incidents remains unknown, primarily due to delayed investigations and insufficient record-keeping practices prevalent in Bangladesh.

7. Regression Analysis to Develop Mathematical Model.

Across numerous research domains (Abdullah, 2021; Awal and Abdullah, 2021; Abdullah et al., 2022), adopting regression analysis often demands the inclusion of multiple independent variables. Given the intricate nature of most scientific investigations, implementing a multiple regression model becomes imperative for forecasting significant outcomes (Walpole et al., 2012). This study's objective is to construct a mathematical framework utilizing the least-squares method, with a specific focus on a multiple linear regression model. The aim is to anticipate accidents and discern the principal factors contributing to inland waterway accidents through regression analysis. Within this segment, we delve into the statistical correlation between the frequency of inland waterway accidents (the dependent variable) and the leading causes of these accidents (the independent variables). To construct the mathematical model, a linear equation is selected, as depicted below.

$$IWA_N = f(A_C, A_{SW}, A_{EC}, A_G, A_O) \quad (1)$$

Where IWA_N represents the number of inland waterway accidents which is the dependent variable. A_C, A_{SW}, A_{EC}, A_G, A_o Indicate the number of accidents that occurred due to collision, stormy weather, excessive current, grounding, and overloading respectively and these causes are the independent variables.

A multiple linear regression model is one in which the coefficients are linear. The multiple linear regression approach sets up the relationship between the dependent and independent variables in order to predict the dependent variable against a collection of independent variables using data from both. The regression model in this study is considered as the following:

$$y = f(x_1, x_2, x_3, ...x_k) \quad (2)$$

Here, y represents the dependent variable that is the number of inland waterway accidents and x_1, x_2, x_3….. etc. are independent variables such as accidents due to collision, stormy weather, overloading, etc. There can be k number of independent variables.

Equation 1 can be written as follows considering all the variables:

$$y_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + ... + b_k x_{ki} \quad (3)$$

Where, $i = 1, 2, 3......, n$ and b_1, b_2, b_3,….., b_k are the regression coefficients that need to be determined to construct the multiple linear regression model.

The multiple linear regression model can be expressed with a residual term as:

$$y_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + ... + b_k x_{ki} + e_i.......... \quad (4)$$

In this case, e_i is the model's residual with the lowest possible value. As a result, the sum of errors (SSE) should be kept minimum. SSE can be expressed as follows:

$$SSE = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - b_0 - b_i x_{1i} \cdots - b_k x_{ki})^2 \quad (5)$$

Different coefficients b_0,b_1,...,b_k are used to differentiate the equation (4). The results are set to zero, and the equations are found as follows. The total number of equations available are *k+1*.

$$n * b_0 + b_1 \sum_{i=1}^{n} x_{1i} + b_2 \sum_{i=1}^{n} x_{2i} + \ldots b_{ki} \sum_{i=1}^{n} x_{ki} = \sum_{i=1}^{n} y_i \quad (6)$$

$$b_0 \sum_{i=1}^{n} x_{1i} + b_1 \sum_{i=1}^{n} x_{1i}^2 + b_2 \sum_{i=1}^{n} x_{1i} x_{2i} + .. + b_{ki} \sum_{i=1}^{n} x_{1i} x_{ki} = b_{ki} \sum_{i=1}^{n} x_{1i} y_i \quad (7)$$

$$b_0 \sum_{i=1}^{n} x_{2i} + b_1 \sum_{i=1}^{n} x_{1i} x_{2i} + b_2 \sum_{i=1}^{n} x_{2i}^2 + .. + b_{ki} \sum_{i=1}^{n} x_{2i} x_{ki} = b_{ki} \sum_{i=1}^{n} x_{2i} y_i \quad (8)$$

....

....

....

$$b_0 \sum_{i=1}^{n} x_{ki} + b_1 \sum_{i=1}^{n} x_{ki} x_{1i} + b_2 \sum_{i=1}^{n} x_{ki} x_{2i} + .. + b_{ki} \sum_{i=1}^{n} x_{ki}^2 = b_{ki} \sum_{i=1}^{n} x_{ki} y_i \quad (9)$$

The compiled datasets provide the foundation for computing essential statistical parameters. Through the substitution of particular values into the previously outlined equations, these equations can be reconfigured into a cohesive system of simultaneous equations. Employing a conventional approach to solve these interconnected equations enables the derivation of regression coefficients and the subsequent equation for the predictive model.

In appraising the efficacy of this mathematical model, several statistical parameters have been considered. The criteria and statistical measures taken into account for this study are elaborated upon below.

7.1. *Variance Inflation Factor (VIF).*

In multiple linear regressions, it is a fundamental assumption that the data does not exhibit multicollinearity. This situation arises when independent variables are closely interconnected. When a correlation exists between predictors, it leads to an elevation in the standard error of predictor coefficients and an increase in their variance. To quantify this shift, the Variance Inflation Factor (VIF) proves to be an invaluable tool, enabling the calculation and assessment of the extent of this escalation. The formula provided below is utilized to ascertain the VIF value.

$$\text{VIF} = \frac{1}{1 - R^2}$$

Here, R^2 symbolizes the coefficient of determination for the regression model. If the VIF score equals or exceeds 5, indicating a substantial correlation among independent variables, it's advisable to reconsider the regression model's validity, as highlighted by Daoud in 2017.

7.2. *Coefficient of Determination (R^2).*

The coefficient of determination, also known as the coefficient of multiple determination, is a measure of how much variation in a dependent variable is caused by a group of independent variables. The coefficient of multiple determination is expressed as follows according to (Levine et al., 2005):

$$R^2 = \frac{SSR}{SST}$$

Where

SSR= The regression sum of squares. Theoretically, SSR is equal to the sum of the squared differences between the predicted value of y and, the mean value of y

SSE= SSE is the sum of the squared differences between the observed value of y and the predicted value of y.

SST= The total of SSR and SSE

In addition to R^2, the adjusted R^2 is an important criterion in multiple linear regression. It is used to compare two or more regression models that forecast the same dependent variable. The corrected R^2 expression is as follows:

$$R^2{}_{(adj)} = 1 - \left[(1-R^2)\frac{n-1}{n-k-1}\right]$$

Where,

R^2 = Coefficient of multiple determination

k = Number of variables

n = Number of samples

7.3. Standard Error.

The standard error functions as a statistical measure indicating the reliability of an estimate, comparable to the standard deviation seen within a large set of similar estimates. This aspect is duly acknowledged within the scope of this research.

$$s = \sqrt{\frac{SSE}{n-k-1}}$$

The symbols have the usual meaning as explained above.

7.4. F-Statistics.

The F-statistic serves as the pivotal value in F-tests. In essence, the F-statistic represents the ratio of two quantities anticipated to be fairly equivalent under the null hypothesis, resulting in an F-statistic value that approximates this equality. To validate the model, the F-statistic must surpass a critical threshold denoted as $f_{critical}$.

$$F - statistic\ (f) = \frac{\frac{SSR}{k}}{\frac{SSE}{n-k-1}} = \frac{\frac{SSR}{k}}{s^2}$$

7.5. Mallow's C_P Statistic.

Mallow's C_p statistic is a valuable tool in assessing the adequacy of a regression model based on ordinary least squares methodology. Its application finds significance in the process of model selection for predictive purposes, focusing on identifying the optimal model encompassing a subset of predictors. A lower C_p value signifies a more accurate model fit. The computation of the C_p statistic follows the formula provided by Rawlings in 1998.

$$C_p = \frac{SS(RES)_p}{MSE_{all}} + 2(p+1) - n$$

Here,

p = Number of independent variables

$SS(Res)_p$ = residual sum of the square from the p number of the variable subset.

MSE_{all} = Mean square error

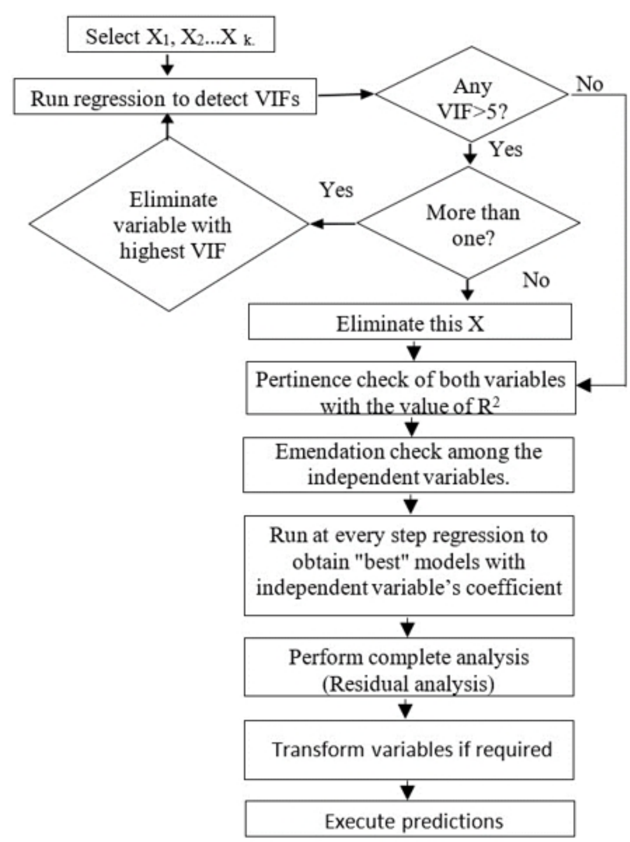
n = Number of samples

In appraising the efficacy of this mathematical model, several statistical parameters have been considered. The criteria and statistical measures taken into account for this study are elaborated upon below.

7.6. Model Development Steps.

This study introduces a methodology that utilizes the multiple regression theory to identify the primary cause of inland waterway accidents. The first step involves selecting independent variables that play a significant role in predicting the number of accidents. Subsequently, the multicollinearity among these independent variables is assessed using the Variation Inflation Factor (VIF). Scatter plots examine the linearity between the dependent and independent variables. Finally, stepwise regression is conducted to determine the optimal subset of independent variables. Once the optimal independent variables are selected, the next step involves determining the best-fitting model based on satisfying various statistical parameters such as R-Squared, Adjusted R-squared, Mean Squared Error (MSE), and Cp. Following the selection of the best subsets, a final analysis is performed to investigate the pattern between the residuals and predicted variables, as well as the independent variables, which is referred to as residual analysis. If any violations are detected in terms of linearity or other assumptions, variable transformations may be necessary. Subsequently, the model is finalized for predicting the number of accidents and identifying influential factors contributing to inland waterway accidents in Bangladesh. The flowchart illustrating this methodology is presented in the accompanying figure.

Figure 3: Timewise distribution of waterway accidents.



Source: Authors.

Following the progression of model development, the collinearity statistics pertaining to the independent variables are presented in Table 1. The tabulated data reveals that none of the VIF values exceed the predefined threshold mentioned earlier.

Table 1: Different mathematical models with required parameters.

Independent Variable	Collinearity Statistics VIF (Including all variables)
Collision (C)	1.130
Stormy Weather (SW)	1.159
Excessive Current (EC)	1.077
Grounding (G)	1.035
Overloading (O)	1.165

Source: Authors.

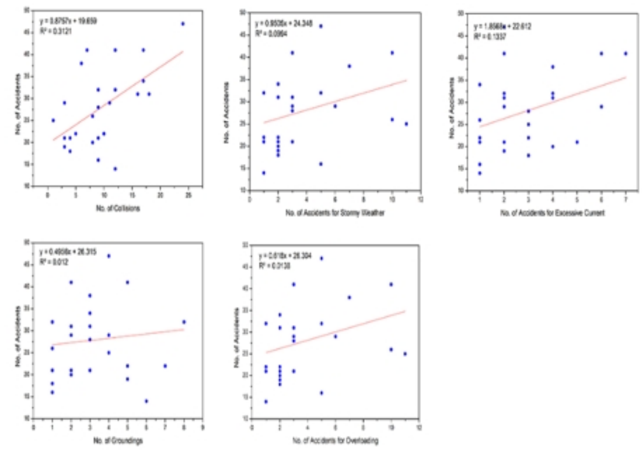
7.7. Correlation Check of Dependent and Independent Variable.

Once the multicollinearity of all independent variables has been assessed in the preceding section, a correlation analysis is conducted to examine the relationship between the dependent variable and independent variables. The correlation values between the dependent variable (Number of accidents) and the independent variables (Collision, Excessive Current, Stormy, Overload, and Grounding) indicate a strong association, as depicted by the scatter plot. Figure 4 shows the scatter plot illustrating the relationship between the dependent variable (number of accidents) and the independent variables. The figure demonstrates that all the independent variables exhibit a positive correlation with the dependent variable, indicated by a positive slope. The R_2 value and positive slope observed in the scatter plot indicate that all the independent variables are suitable for inclusion in the multiple regression analysis. Notably, the collision, stormy weather, and excessive current variables exhibit a strong relationship with the dependent variable, as evidenced by their good coefficient of determination(R_2). While the other two independent variables display a weaker association with the dependent variable, they still meet the VIF criteria for inclusion in the analysis.

8. Best Fit Regression Model.

Once linearity has been verified, the subsequent stage involves the implementation of stepwise regression to identify the optimal subset. In this study, five distinct, independent variables are under consideration. This yields 25 potential combinations ranging from one to five variables. The sorting of these subsets is accomplished by meticulously evaluating model selection criteria. Remarkably, in every instance, the fcritical value proves to be lower than the calculated F statistics (f value). With the selection of the mathematical model concluded, the next step involves residual analysis. Upon plotting residual data for each independent variable, it becomes evident that all corresponding graphs represent irregular patterns, which indicates that the model is ready for the prediction of the number of accidents.

Figure 4: Scatter plot between dependent and independent variables.



Source: Authors.

Table 2: Different mathematical models with required parameters.

$IWA_N = f(A_C, A_{SW}, A_{EC}, A_G, A_O)$	$IWA_N = f(A_C, A_{SW}, A_{EC}, A_G)$	$IWA_N = f(A_C, A_{SW}, A_{EC})$	$IWA_N = f(A_C, A_{SW})$	$IWA_N = f(A_C)$	Different Mathematical Model
0.78	2.86	6.01	12.371	19.659	a
1.096	1.04	1.03	1.06	0.87	C
1.52	1.62	1.64	1.45	NA	SW
0.84	2.19	2.046	NA	NA	EC
0.801	0.81	NA	NA	NA	G
2.10	NA	NA	NA	NA	O
5.07	5.13	5.276	6.323	7.48	s
0.74	0.72	0.688	0.53	0.31	R^2
0.67	0.66	0.643	0.488	0.28	R^2_{adj}
25.72	26.29	27.84	39.983	56.019	$MSE_{(residual)}$
6.0	5.4	5.7	15.2	29.1	C_p
10.76	12.81	15.43	12.42	10.434	f
2.74	2.87	3.07	3.44	4.28	$f_{critical}$ (0.05)

Source: Authors.

9. Discussion.

This study establishes a direct correlation between the frequency of accidents and the intensity of vessel traffic on specific river routes. Unfortunately, the busiest transportation routes in Bangladesh, specifically Barishal and Chattogram, have been witness to the highest number of accidents in the last two decades. The distribution of accidents over the course of a day highlights their persistent occurrence, with a notable prevalence during daylight hours as opposed to nighttime. Of particular concern is the alarming revelation that the majority of accidents peak between 10 AM and 4 PM. This time window coincides with Bangladesh's bustling business hours when a considerable influx of passengers and business personnel relies on waterways for transportation.

Furthermore, this study delves into five key factors contributing to maritime accidents, treating them as distinct, independent variables for the creation of an innovative mathematical model. The outcomes of this endeavor are presented in Table 2, encompassing coefficients and pertinent statistical attributes associated with the mentioned five independent variables. These statistical parameters are required to align with the model's standards criterion. In Table 2, the most optimal subsets are displayed, carefully chosen from a pool of 2^5 diverse combinations. It also provides a vivid demonstration of how the rise in the R^2 value (coefficient of multiple determination), coupled with the incorporation of independent variables, stands as the principal criterion for selecting the most suitable subset and validating the model's adequacy. Furthermore, the model selection criteria encompass key factors such as achieving the highest adjusted R^2 value, the lowest mean square error (MSE) value, the minimum standard error value, and the lowest C_P value. Based on these criteria, the best model is identified as IWA_N, f $(A_C, A_{SW}, A_{EC},\ A_G,\ A_o)$ because most of the criteria are in line with the model validation requirements. However, by considering all independent variables (accident parameters), the final model chosen for identifying the influential parameters and estimating the number of maritime fatalities is based on the highest R^2 value, and the developed mathematical model is as follows:

Best fit model:

$$y = 0.782 + 1.096*C + 1.52*SW + 0.801*G + 2.1*O + 0.84*EC \tag{10}$$

Although there is no significant difference in the values of R^2, adjusted R^2, standard error, and mean square error (MSE) between the models IWA_N = f $(A_C, A_{SW}, A_{EC},\ A_G,\ A_o)$ and IWA_N =f $(A_C, A_{SW}, A_{EC},\ A_G)$, it is recommended to use the former model for assessing the accident because it has an additional independent variable. From the best-fit model (Equation 10) it is clear that the most influential parameter (high coefficient value 2.1) for the accident is the overloading of the ship. Practically it is also found that most of the accidents are occurred for overloading in Bangladesh (Mia et al., 2021). The next two influential parameters are stormy weather and collision, with coefficient values of 1.52 and 1.096. Over the year, there is a rainy season in Bangladesh, when the weather becomes very rough both day and night. For these bad or stormy weather conditions, accidents have occurred during the time travel. Another two parameters, such as G (grounding) and excessive current, EC, have less coefficient value, representing that those parameters have less effect on accidents. One thing must be mentioned: adding the variable grounding R^2 did not improve significantly. So, it is clear that grounding causes a lesser number of accidents.

While there are no statistically significant differences observed in the metrics of R^2, adjusted R2, standard error, and mean square error (MSE) between the two models, namely IWA_N = f $(A_C, A_{SW}, A_{EC},\ A_G,\ A_o)$ and IWA_N =f $(A_C, A_{SW}, A_{EC},\ A_G)$, it is advisable to opt for the former model when evaluating accidents due to its inclusion of an additional independent variable which is more convenient to predict the number of accident. As deduced from the optimal fit equation (Equation 10), the preferred model highlights the preeminent factor—ship overloading—with a substantial coefficient value of 2.1, signifying its pronounced influence on accidents. This observation aligns with empirical findings illustrating that a significant portion of accidents in Bangladesh result from overloading incidents (Mia et al., 2021). The subsequent noteworthy parameters contributing to accidents are stormy weather and collisions, yielding coefficients of 1.52 and 1.096, respectively. Bangladesh experiences a distinct rainy season, characterized by turbulent weather conditions day and night. These adverse weather conditions have been associated with accidents during travel. Conversely, grounding (G) and excessive current (EC) parameters exhibit comparatively lower coefficient values, suggesting their minor impact on accidents. Beyond theoretical explanations, it is essential to delve into practical perspectives. Within this context, it becomes evident that SW (stormy weather) and C (collision) share an intimate relationship, sometimes intricately linked as causal factors. Collisions can transpire due to stormy weather conditions, further underscoring their interdependence. Moreover, the emergence of EC (excessive current) can also find its origins in stormy weather scenarios. As we bridge our model with real-world scenarios, a compelling revelation comes to light: the intricate interplay of variables, where one can act as the catalyst for another, ultimately precipitating the occurrence of accidents. Notably, including the grounding variable did not yield a substantial enhancement in R^2. In essence, grounding contributes to fewer accidents, further affirming its limited influence.For model validation, we assessed the performance of our final model (equation 10) by comparing its results with accident data from the past three years. This analysis yielded a favorable approximation, thereby validating the predictive capability of our model. We calculated the model's estimated accident values for these three years and summarized them alongside the actual data in Table 3.

Table 3 reveals that, for one year, the model's predictions exceeded the actual values, while for two cases, the model's predictions fell below the actual figures. In our best-fit model utilizing the data from the last three years, we observed a maximum error of nearly 36.94%. The deviation values generally fell within a range of ±34%, closely aligning with our model's estimated error of 26%. In Table 3, the model's accuracy, rep-

Table 3: Case study of Accidents (Actual values and Model values).

Year	Total Accidents	Predicted Accidents	Error %
2020	36	47	32.03
2021	37	26	-28.77
2022	26	18	-36.94

Source: Authors.

resented by the R-square value, is 0.74. This value is significant as it is a robust justification for our model. It implies that 74% of the variation in the dependent variable can be attributed to changes in the independent variables, leaving a 26% margin for estimation error. Notably, this estimation error closely resembles the deviation values presented in Table 4, and it is likely due to the omission of certain influential independent variables—a factor that can be addressed in future research. Despite this, our case studies have yielded satisfactory outcomes for the developed model over selected years.

Conclusion and Recommendations.

Due to its affordability, water-based transportation is a favored choice among individuals in Bangladesh. Restoring the former glory of the region's waterways would alleviate the strain on-road vehicles and significantly reduce pollution and the frequency of accidents. The distressing sounds of mourning and grief resulting from accidents on inland waterways should not be tolerated. It is the collective aspiration of the community that waterway transportation becomes a safe and peaceful mode of travel. This research paper thoroughly examines the most common and critical independent variables that primarily influence the total count of maritime accidents in selected locations across Bangladesh. Additionally, the article establishes a robust correlation between dependent and independent variables using a mathematical equation, utilizing multiple linear regression. The validity of this equation is confirmed through essential statistical parameters, ensuring its adequacy for the system. By applying this model, it is also observed that the predicted results closely align with practical outcomes. Further investigations can be conducted to enhance future results by collecting and analyzing more sample data and using different independent variables. However, the author intends to present immediate recommendations that can be easily implemented to prevent marine accidents.

- Foggy weather and insufficiency of navigation tools and marking are a reason behind collision-type accidents. A ship needs to control with more caution in foggy weather and a sufficient amount of navigation tools and marking need to be installed and should be checked properly before every departure.
- Sometimes maritime professionals are not enough skilled to run a ship in stormy weather or excessive current time. There is shortage of basic training as well as route information. So, more practical based training programs need to be added.
- Overloading is another reason for accidents. During holidays most of the vessels take more passengers and goods than its capacity for extra profit. Overloading disturbs the stability of a ship and sometimes it capsizes.
- The use of AI (Artificial Intelligence) should be introduced to improve the maritime safety situation of the country. The use of data science and machine learning can produce some useful assumptions about weather conditions. It can reduce accidents due to foggy or uncooperative weather.
- Mass awareness should be taken on a serious note. Most of the passengers are unaware of safety issues, they do not even know how to use life jackets, lifebuoys, etc. This is causing unwanted casualties. Live-saving appliances and safety measures should be ensured.

Furthermore, it is important to note that many ships in Bangladesh are not being adequately maintained. Frequently, minor issues are overlooked and left unaddressed, leading to increased operational costs. Consequently, these issues should be thoroughly examined before each voyage. Additionally, the respective authority should exercise more vigilant oversight of vessels to ensure compliance with the Inland Shipping Ordinance rules, as many local vessels currently do not adhere to these regulations. Hence, comprehensive assessments of vessels should be conducted under rigorous monitoring. Moreover, the authority should undertake effective investigations of every accident. Conducting impartial investigations will enable the authority to make well-informed decisions to prevent maritime accidents.

Acknowledgements.

The authors would like to thank Department of Shipping (DOS), Bangladesh Inland Water Transport Authority (BIWTA) and the Accident Research Institute (ARI), BUET for giving the data and other required information, which also helped immensely in this research.

References.

Abdullah, A. (2021). *Development of a mathematical model for ship repair time estimation* [Master's Thesis, Bangladesh University of Engineering and Technology (BUET)]. BUET Central Library. http://lib.buet.ac.bd:8080/xmlui/handle/123456789/-5943.

Abdullah, A., Rahman, H., Uddin, M. I., & Mia, M. J. (2022) A General Method to Develop Mathematical Model for Estimating Ship Repairing Man-Hour. *1st International Conference on Mechanical, Manufacturing and Process Engineering (ICMMPE 2022), DUET. [Online] Available:https://scholar.-google.com/citations?view_op=view_citation&hl=en&user=X9-rlUxMAAAAJ&citation_for_view=X9rlUxMAAAAJ:iH-uZ7U-c-o4C.*

Akhter, S. (2017). Unregistered Vessels Put Public Safety at Risk". Available from: http://www.newagebd.net/article/15986/-unregistered-vessels-put-public-safety-at-risk [Accesed 12 August 2023].

Awal, Z. I., & Abdullah, A. (2021). Multiple linear regression model for ship repair time estimation. *12th International Conference on Marine Technology (MARTEC 2020), Ambon, Indonesia.* [Online] Available: https://scholar.google.com/citations?view_op=view_citation&hl=en&user=X9rlUxMAAAAJ-&citation_for_view=X9rlUxMAAAAJ:j3f4tGmQtD8C.

Awal, Z. I., Islam, M. R., & Hoque, M. M. (2007). Marine vehicle accident characteristics in bangladesh: study on collision type accidents. In *Proceedings of the 7th International Conference on Mechanical Engineering (ICME 2007)* (pp. 29-31).

Azad, A. K. (2009). *Riverine Passenger Vessel Disaster in Bangladesh: Options for Mitigation and Safety*. Master's Thesis in Disaster Management, BRAC University, Dhaka.

Baten, C. A. A. (2005). Internal water transportation system: safety of inland Passenger vessels. *NDC E-JOURNAL*, *4*(1), 131-157.

Banglapedia (2021). River and Drainage System Available from: https://en.banglapedia.org/index.php/River_and_Drainage-_System. [Accesed 12 August 2023].

Bdnews24 (2019). Marine accidents on the decline,' claims Directorate of Naval Affairs. Available from: https://bangla.bdnews24.com/bangladesh/article1609112.bdnews [Accesed 12 August 2023].

Bengali Tribune (2019). 535 major marine accidents in 14 years. Available from: https://www.banglatribune.com/national/-411375 [Accesed 12 August 2023].

BIWTA (2021). Bangladesh Inland Water Transport Authority. Available from: https://biwta.gov.bd/site/page/aea3e3d9-0e99-4bcd-9330-a0a9961c793c/aboutus[Accesed 12 August 2023].

Chowdhury, A. S. (2005). *Waterway accident characteristics assessment and information system development.* Master of Engineering Thesis, Bangladesh University of Engineering and Technology, Dhaka.

Daoud, J. I. (2017). Multicollinearity and regression analysis. In *Journal of Physics: Conference Series* (Vol. 949, No. 1, p. 012009). IOP Publishing.

Haque, S. (2017). 6408 killed in launch accidents in 20 years, Manavjimon. Available from: https://mzamin.com/details-archive2016.php?mzamin=64287&cat=2 [Accesed 12 August 2023].

Huq, N. A., and A. M. Dewan. 2006. "Launch Disasters in Bangladesh: A Geographical Study." *Geografia: Malaysian Journal of Society and Space* 1 (2): 14–25.

Iqbal, K. S., Bulian, G., Hasegawa, K., Karim, M. M., & Awal, Z. I. (2008). Possible remedies for intact stability hazards involving contemporary small inland passenger ferries in Bangladesh. *Journal of marine science and technology*, *13*, 282-290.

Khalil, G. M., & Tarafder, M. S. (2004). Ferry disasters in the rivers of Bangladesh: some remedial measures. *The Journal of National Oceanographic and Maritime Institution*, *21*(2), 33-53.

Levine, D., Stephan, D., Krehbiel, T. and Berenson, M. (2005). Statistics for Managers using Microsoft Excel. *Prentice Hall. ISBN 0-536-04080 X.*

Mia, M. J., Uddin, M. I., Awal, Z. I., & Abdullah, A. (2021a). An era of inland water transport accidents and casualties: The case of a low-income country. *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, *5*(2), 32-39.

Mia, M. J., Islam, M. A., & Akter, M. (2021b). Contribution of Ganges-Brahmaputra Delta for Developing the Sustainable Blue Economy in Bangladesh. *Int. J. Sci. Res. in Multidisciplinary Studies Vol*, *7*(6).

Mia, M., Islam, M. S., Islam, M. A., Islam, M., & Uddin, M. (2020). Brief analysis of inland waterway accidents in bangladesh: Causes and solutions. In *12th International Conference on Marine Technology (MARTEC 2020) At: Faculty of Engineering–Pattimura University, Ambon, Indonesia*.

Mostofa, K. (2021). Dangerous waterways in fog due to lack of modern equipment. Available from: https://sarbojonkotha.info/sk-25-structural-roots-accident [Accesed 12 August 2023].

Probha, N. A., & Hoque, M. S. (2018, December). A study on transport safety perspectives in bangladesh through comparative analysis of roadway, railway and waterway accidents. In *Proceedings of the Asia-Pacific Conference on Intelligent Medical 2018 & International Conference on Transportation and Traffic Engineering 2018* (pp. 81-85).

Rahman, N. A., & Rosli, H. Z. (2014). An innovation approach for improving passenger vessels safety level: overload problem. *International Journal of Business Tourism and Applied Sciences*, *2*(2), 1-14.

Rahman, S. (2017). An analysis of passenger vessel accidents in Bangladesh. *Procedia engineering*, *194*, 284-290.

Rawlings, J.O., Pantula, S.G. and Dickey, D.A. (1998). Applied regression analysis: a research tool. *Springer Science & Business Media. ISBN 0-387-98454-2*.

Stornes, P. (2015). Risk influencing factors in maritime accidents. An exploratory statistical analysis of the Norwegian Maritime Authority incident database. *NTNU Social Research.*

Uddin, M. I., Islam, M. R., Awal, Z. I., & Newaz, K. M. S. (2017). A study of inland water transport accidents of Bangladesh: Lessons from a decade (2005-2015). *Procedia Engineering*, *194*, 291-297.

Walpole, R.E., Myers, R.H., Myers, S. and Ye, K. (2012) Probability & Statistics for Engineers & Scientists. *Prentice Hall. ISBN 10: 0-321-62911-6.*

Wang, Y., Ou, Y., Deng, X., Zhao, L., & Zhang, C. (2019). The ship collision accidents based on logistic regression and Big Data. *Chinese Control And Decision Conference (CCDC)*. https://doi.org/10.1109/ccdc.2019.8832686.

Zhao, J., &; Lv, J. (2016). Comparing prediction methods for maritime accidents. *Transportation Planning and Technology, 39(8), 813–825.* https://doi.org/10.1080/03081060.2016.-1231901.