PASSENGERS' PERCEPTION OF WATERWAY SAFETY: A BAYESIAN BELIEF NETWORK APPROACH IN THE DHAKA-BARISHAL ROUTE

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ABSTRACT

Bangladesh's Inland Water Transport System (IWTS) is a popular mode of transportation due to its extensive waterway network. It is also crucial for economic trade, disaster response, and connecting remote areas while promoting environmental sustainability and tourism. Despite its significance, passenger safety perception remains rarely scrutinized. This research investigates the possible impacts of various factors encompassing passengers' socioeconomic demographics, travel patterns, and safety concerns on their perception of safety related to this mode. The methodology employs a comprehensive questionnaire and in-person interviews, capturing various aspects of passengers' experiences and perceptions. The data was gathered from a sample of 260 individuals who were passengers on the Dhaka-Barishal launch route, a prominent inland water transportation route inside the country. The response variable, passengers' safety perception, is based on several questions about the onboard safety facilities. A Bayesian Belief Network (BBN) is employed to examine the inherent relationships among the independent variables and assess their influence on the safety perception of the passengers. The network underwent adjustments based on the interconnections among variables and by referring to relevant sources. Furthermore, factors that significantly influence an individual's perception of safety are identified through sensitivity analysis. Notably, satisfaction with health services, food quality, and overall service quality emerged as significant contributors. Experiences

with accidents, harassment, engine breakdowns, and pickpocketing also wielded a substantial influence on perceived safety. These findings suggest that sharing safety resources and providing information on safety protocols can alleviate concerns related to past incidents, fostering a safer environment. Implementing stringent safety policies, coupled with well-trained security personnel, is crucial for minimizing accidents and enhancing passenger security during the journey. Therefore, the significance of the study lies in its potential to steer policymakers and stakeholders towards targeted interventions, optimizing safety equipment and ultimately refining the overall quality of water transportation services. In conclusion, this research will help to bridge a critical gap by investigating passengers' safety perception within Bangladesh's IWTS and improve the service overall.

Keywords: *Bayesian Belief Network, water transport, safety perception, travel pattern, travel safety concern*

1. INTRODUCTION

In Bangladesh, a country with numerous rivers, inland water transport is an integral part of the transportation system. Its affordability and accessibility make it a popular choice for both people and goods transportation in southern regions such as Barisal, Jhalokathi, Bhola, Borguna, Patuakhali and Pirozpur connected to Dhaka. Particularly, the route from Dhaka to Barishal was immensely busy before the completion of the Padma Bridge due to limited economic alternatives. Approximately

50,000 individuals used to travel to various coastal areas, including Barisal, by launch from Dhaka daily before the Padma Bridge was inaugurated ("Dhaka's launch passengers drop by 34% in a year", 2023). However, despite the extensive waterway network and its transportation importance, safety in this sector is far from guaranteed. The lack of attention to safety has left this mode vulnerable to numerous risks. Especially, the perception of safety among passengers was not given any attention at all. According to a recent study, there have been 248 motor launch accidents since 1977 which caused the loss of 2,309 lives with 374 people injured and 208 people missing (Mia et al., 2021). Whereas a news article from 2020 reported a total of 171 small and big launch accidents between 2010 to 2019 with casualties reaching up to about 623 individuals (Ahmed, 2020). Additionally, an article from 2014 revealed that in a span of over 38 years between 1976-2012, more than four thousand people lost their lives in major marine accidents while around 6,000 individuals lost their lives and more than 700 people are missing in 535 major inland ship accidents in the country (Karim, 2014). In 2017, 27% of reported inland water accidents involved cargo ships, while 26.3% were attributed to passenger vessels (Uddin et al., 2017). Though the data from these sources highlight the alarming frequency and devastating impact of water transport accidents in Bangladesh, it should be noted that numerous accidents and related information also often go unreported. With the rising number of crashes and limited endeavours to improve waterway safety, passenger concerns are increasing daily. Recognizing that various viable modes of transportation now exist beyond the waterway, to ensure the sustainability of this particular mode, it is imperative to enhance passenger perceptions, particularly with regard to safety. A recent study assessed passengers' perceptions to evaluate their satisfaction with the quality of service on water vessels, with safety being one of the key factors (Rashid et al., 2023). However, there has been minimal research dedicated to examining passengers' perception of safety in order to mitigate the risk of water vessel accidents. Most studies were based on crash data analysis but neglected how such objective risk factors affected the subjective perception of safety among passengers and potential strategies for enhancing this perception. Thus, necessitating the accurate evaluation of their opinions regarding factors impacting safety. In order to accurately examine the opinions of passengers regarding the perceived safety concerns related to this mode, face-to-face interviews were conducted with 260 individuals on the Dhaka-Barishal river route. The survey covered demographic factors and travel characteristics of the passengers to gain accurate data. A Bayesian Belief Network (BBN) was utilized then to examine the impact of various factors on passengers' safety perceptions concerning inland waterway transportation, particularly launches. BBN also enabled this study to explore the underlying relationships of the independent variables and determine the most significant variables affecting the passengers' perception.

2. LITERATURE REVIEW

This comprehensive literature review undertakes an in-depth investigation, systematically categorizing diverse aspects associated with the determinants that may influence the safety of waterway transportation services. The primary focus is on investigating the impact of socioeconomic and demographic characteristics, along with travel experience, and highlighting their interconnections with passengers' perceptions of the safety on the ships. Each potential factor affecting safety is discussed below.

Examining the factors that contribute to passengers' perceptions of safety onboard reveals a crucial association with the availability and quality of health services. Wise (2020) found that shortages in medical staff and funding contribute to these concerns. Even when there are sufficient medical staff, their skill level influences passengers' perceived safety, as demonstrated in a study by Venesoja et al. (2020). Moreover, a study in Pakistan by Atif et al. (2021) highlighted that medicine shortages impact patient care and safety. Bilir et al.'s (2023) research on German-flagged container ships suggested that telemedical contact is often needed, implying potential competence issues with onboard medical staff. These findings collectively emphasize the importance of evaluating and enhancing onboard health services for optimal safety perception. However, health services are not the only factor that affects passengers' perception of safety onboard.

In addition to the availability and quality of health services, another factor that influences passengers' perception of safety onboard is the access to healthy food. But the aspect of access to healthy food is often overlooked in the context of public transportation (Leuthart et al., 2021). A study conducted in 2017 delved into the preferences and perceptions of airline passengers regarding in-flight food and beverages. It was found that passengers significantly valued the freshness and healthiness of the food served on board (Dolekoglu, 2017).

Additionally, the quality of service provided by a transportation mode plays an important role in shaping passengers' perception of safety. A 2021 study on the Vietnam to Australia route supports this idea, indicating that passengers' general satisfaction with the airline service has a notable impact on their safety perception (Shiwakoti et al., 2022). Perceived safety is heavily influenced by different elements of service quality, including dependability, hygiene, and convenience. High levels of service quality lead passengers to consider the transport system as more secure and trustworthy (Nguyen-Phuoc et al., 2021).

Another element that can impact an individual's perception of safety is experiencing criminal incidents such as burglary, robbery, and pickpocketing. These experiences can alter one's perspective of their environment and create feelings of vulnerability, an effect that is especially noticeable among women (Loewen et al., 1993). High-profile incidents and accidents also play a crucial role in shaping passengers' perception of safety. For instance, accidents like shipwrecks can have severe repercussions, reducing passengers' confidence in their safety (Vidmar & Perkovič, 2015). Incidents like these can leave a lasting impression, significantly impacting the perception of safety (Lois et al., 2004). In a separate investigation, researchers examined 92 individuals involved in motor vehicle accidents and evaluated them for acute stress disorder within one month. Another group of 71 survivors was reevaluated for posttraumatic stress disorder six months after the trauma, suggesting that previous traumatic experiences may impact the onset of posttraumatic stress disorder (Sherry & Philbrick, 2003). Furthermore, past negative experiences, such as motion sickness during travel, can heighten a passenger's perception of risk, making them feel unsafe (Asua et al., 2022). This anticipation of feeling unwell can reduce a passenger's trust in the mode of transportation, further impacting their overall perception of safety (Asua et al., 2022). In summary, both personal experiences with crime and negative incidents during travel can profoundly influence an individual's perception of safety and trust in their environment or mode of transportation.

Building on the previous discussion, an additional aspect to examine is the influence of harassment on passengers' feeling of safety. Research indicates that individuals who have encountered unfavourable incidents like harassment while travelling are inclined to have a skewed perception of safety. (Seriwatana, 2022). A study carried out in China uncovered that harassment can significantly unsettle female passengers and affect their sense of security (Yang et al., 2022). Hence, encountering harassment during travel is considered a significant factor in this scenario.

Despite the extensive research conducted on passengers' safety perceptions, a significant portion of it has been carried out in developed countries, with a primary focus on safety in public transportation systems. However, there is a noticeable research gap in understanding safety perceptions within the waterway transportation sector. This research addresses the lack of attention given to waterway safety perceptions, specifically focusing on passengers in developing countries like Bangladesh. The aim is to offer new insights that will contribute to a more thorough comprehension of how passengers perceive their safety when using inland water transportation. This effort is essential for strengthening safety protocols and enhancing passenger satisfaction in the water transportation industry, particularly within developing nations.

3. METHODOLOGY

3.1 Data Collection

A questionnaire survey was developed based on previous studies and a pilot survey with the local context in mind. The survey was mainly conducted at two river ports: Barishal and Sadarghat. One-on-one interviews were conducted with active waterway passengers, resulting in 260 completed responses. In order to prevent bias, the data was gathered at different times of the day from a diverse group of individuals belonging to various social classes and backgrounds. The questionnaire included a mix of closed and open-ended questions, enabling the collection of both quantitative data and qualitative insights. This strategic approach was instrumental in understanding the complex dynamics at these terminals, forming a solid foundation for subsequent analysis and recommendations. The survey collected data on the following aspects of the respondents e.g., socioeconomic status, travel patterns and their travel experiences. These were the independent variables that could influence the outcome of the study. The dependent variable was perceived safety, which was the main focus of the survey. To measure perceived safety, the survey required passengers to indicate their level of agreement or disagreement with statements related to the safety features and risks of the water vessel. For example, "I think there aren't enough fire extinguishers on the water vessel", "I think there aren't enough life jackets or floaters", etc. The survey used different types of data input methods to capture the responses of the passengers. Some questions required binary inputs, such as yes or no. Some questions allowed open-ended inputs, where passengers could write their answers in words. Some questions used five-point Likert scale inputs, where passengers chose one from five possible options consisting of strongly agree, agree, neutral, disagree and strongly disagree.

3.2 Model Selection

In this study, the Bayesian belief network (BBN) is used to analyze the perceived safety of the passengers. Bayesian network has been used instead of the regression model because a regression model doesn't account for changes in other variables when one variable is changed. Regression models are built on predetermined relationships between dependent and independent variables (Chang & Wang, 2006). In contrast, BBNs can arrange the variables among themselves by determining the most effective arrangement of connections in order to provide an explanation or prediction for the forecast variable. They possess a comprehension of data structures and sort out the strongest connections. The presence of variables within a network implies that they all influence one another, so any modification made to one variable will impact all others. Additionally, adding more variables does not heavily affect the BBN because it examines interdependencies and patterns of relationships and consequences. Even when additional factors are introduced, those with significant impacts based on their distributions still maintain the effects.

A conditional probability table and Directed Acyclic Graph (DAG) are present in a Bayesian network. DAG is a graph structure consisting of nodes connected by directed edges, where the edges have a specific direction, and there are no cycles or loops in the graph. It contains elements called parent nodes and child nodes. The conditional probability table is used to manage and explore uncertainty through a Bayesian interface. The Bayesian hypothesis relies on conditional probability as the foundation of its general framework.

The study utilizes the GeNIe Academic 4.1 Version for structure and parameter learning, incorporating the Peter-Clark (PC) algorithm for structure learning and the Expectation Maximization (EM) algorithm for parameter learning and calculation of marginal probabilities for node generation.

3.3 Model Development

Figure 1 shows the prior marginal probabilities for the BBN model. The arrows flow from parent nodes to child nodes in an acyclic manner. The depicted DAG reflects insights from past literature and the structural learning executed by the PC algorithm.

In the given diagram, gender serves as the parent node, influencing both experienced harassment and perceived safety. Experienced harassment and experienced pickpocketing are parent nodes contributing to perceived safety and service quality. Similarly, accidents and breakdowns experience act as parent nodes for perceived safety and service quality. The sole child node of travel frequency is service quality, which is a parent node to perceived safety. Age is portrayed as the root node, impacting both education and occupation. Education is a parent node for occupation, and both influence monthly income. Monthly income, as a parent node, influences health services and food quality. Health services, in turn, affect experienced motion sickness, both of which are parent nodes for perceived safety. Lastly, food quality acts as a parent node for both perceived safety and service quality.

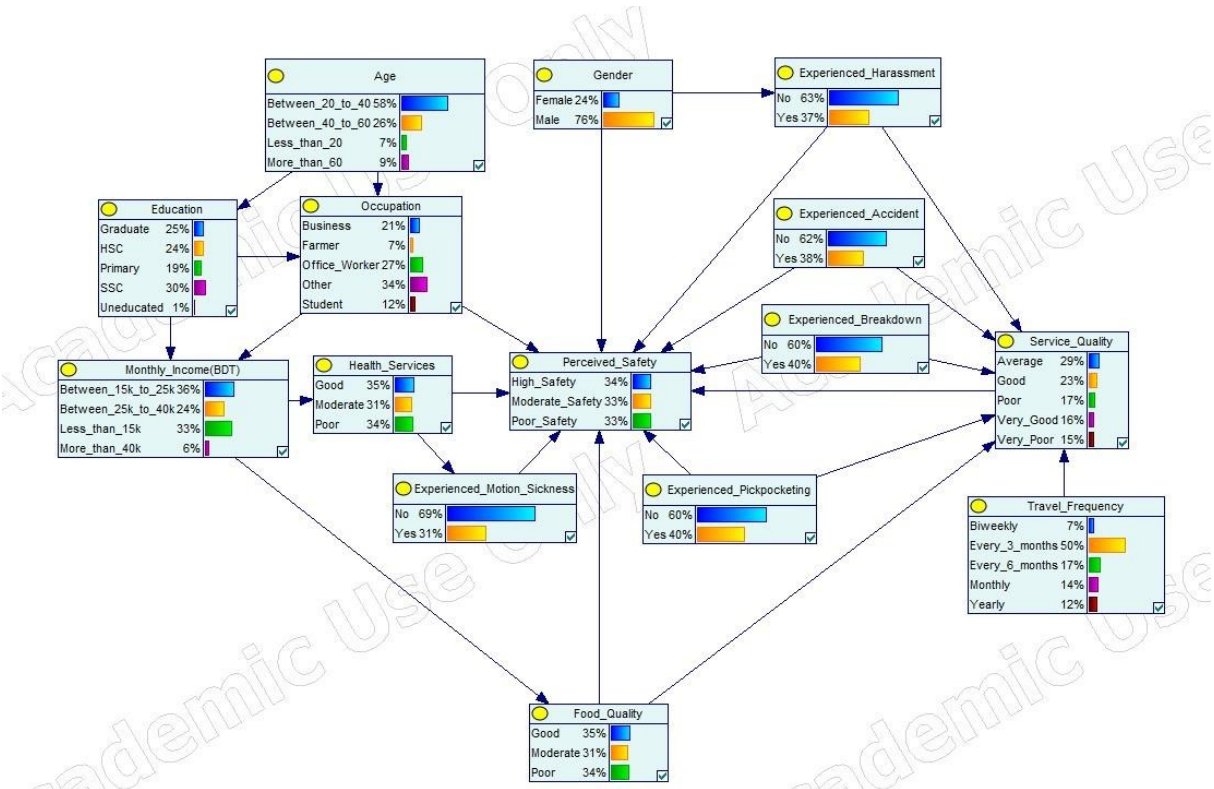

Figure 1: Marginal probability distribution diagram

3.4 Model Validation

Model validation involves assessing its ability to accurately reflect the functioning of an application. The ROC curve presents different thresholds and their corresponding measures of sensitivity versus false positive rate, aiding in determining optimal cut points based on classification costs. The “Leave one out” method was applied during the sensitivity analysis section of the study. Comparing multiple predictive models, the area under the curve AUC measure assesses their efficacy. The obtained AUC values from the ROC curves indicate efficiencies of 0.73, 0.72, and 0.75 for perceived safety levels classified as high, moderate, and poor respectively.

3.5 BBN Analysis

Initially, the 'Poor_Safety' state was established as the observed evidence in the 'Perceived_Safety' node for the classification of passenger attributes associated with the perception of water transportation vessels as unsafe, as depicted in Figure 2. There is a 37% marginal probability of passengers experiencing harassment, in the scenario where the passenger perceives the ship as unsafe. Similarly, the marginal probabilities for passengers encountering an accident and an engine breakdown are 39% and 41%, respectively. Furthermore, the network indicates a marginal probability of 41% for passengers experiencing pickpocketing in this scenario. Additionally, passengers who perceive water vessels as unsafe exhibit a 35% likelihood of rating the health services onboard as

poor, and a corresponding 35% express dissatisfaction with the food quality on the ship. Under these conditions, 18% of passengers deem the ship's service quality poor, while an additional 16% consider it to be very poor.

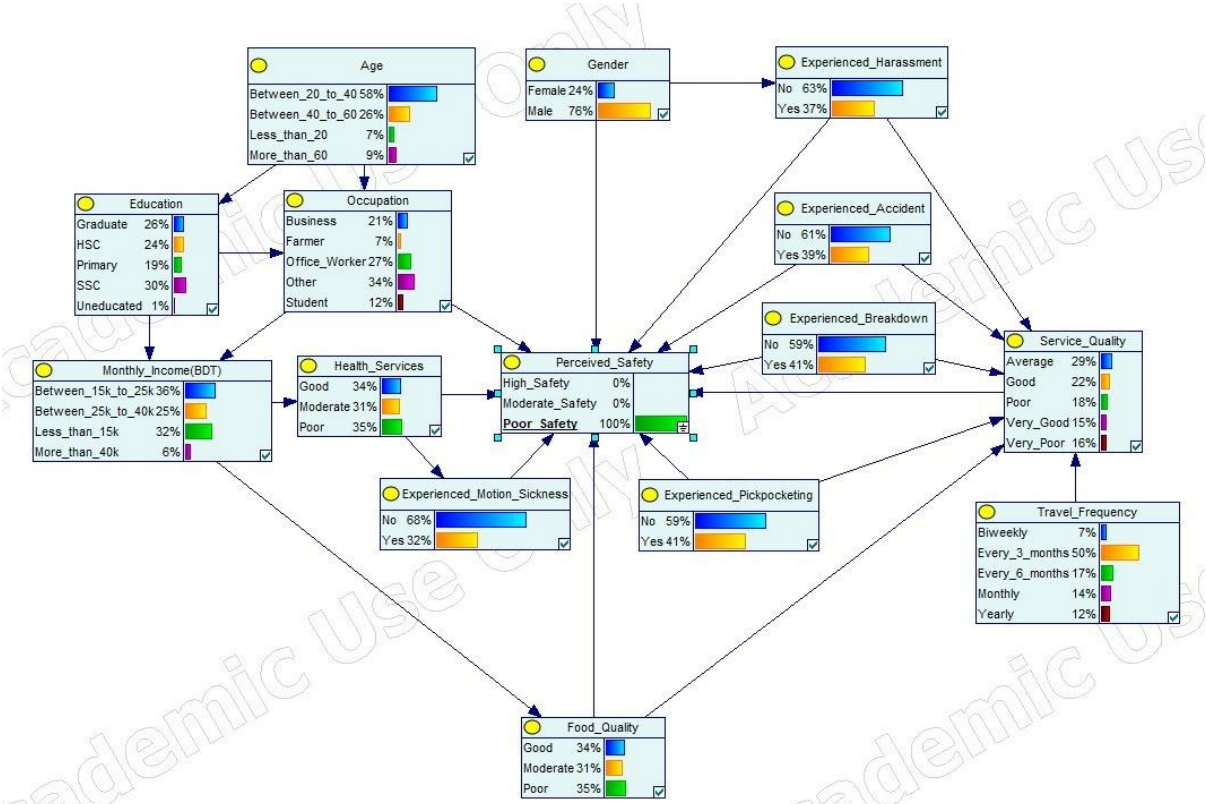

Figure 2: Marginal probabilities setting ‘Poor_Safety’ as evidence.

3.6 Sensitivity Analysis

The sensitivity analysis was conducted using GeNIe software to assess the influence of various factors on the target node 'Perceived_Safety'. Factors indicated in dark red colour have a substantial effect on the target variable, whereas lighter shades indicate weaker effects. The sensitivity analysis highlighted factors such as 'Healthcare_Services', 'Food_Quality', 'Experienced_Accident', 'Experienced_Harassment', 'Experienced_Breakdowns' and 'Experienced_Pickpocketing' in a dark shade of red, indicating their significant impact on the target variable. On the other hand, variables like 'Age', 'Gender' and 'Experienced_Motion_Sickness' appear in a lighter shade of red, suggesting a comparatively lower influence on the target variable compared to the first group. Lastly, variables including 'Education', 'Occupation', 'Monthly_Income(BDT)', 'Service_Quality' and 'Travel_Frequency' show an even fainter shade, indicating the lowest impact on the perceived safety.

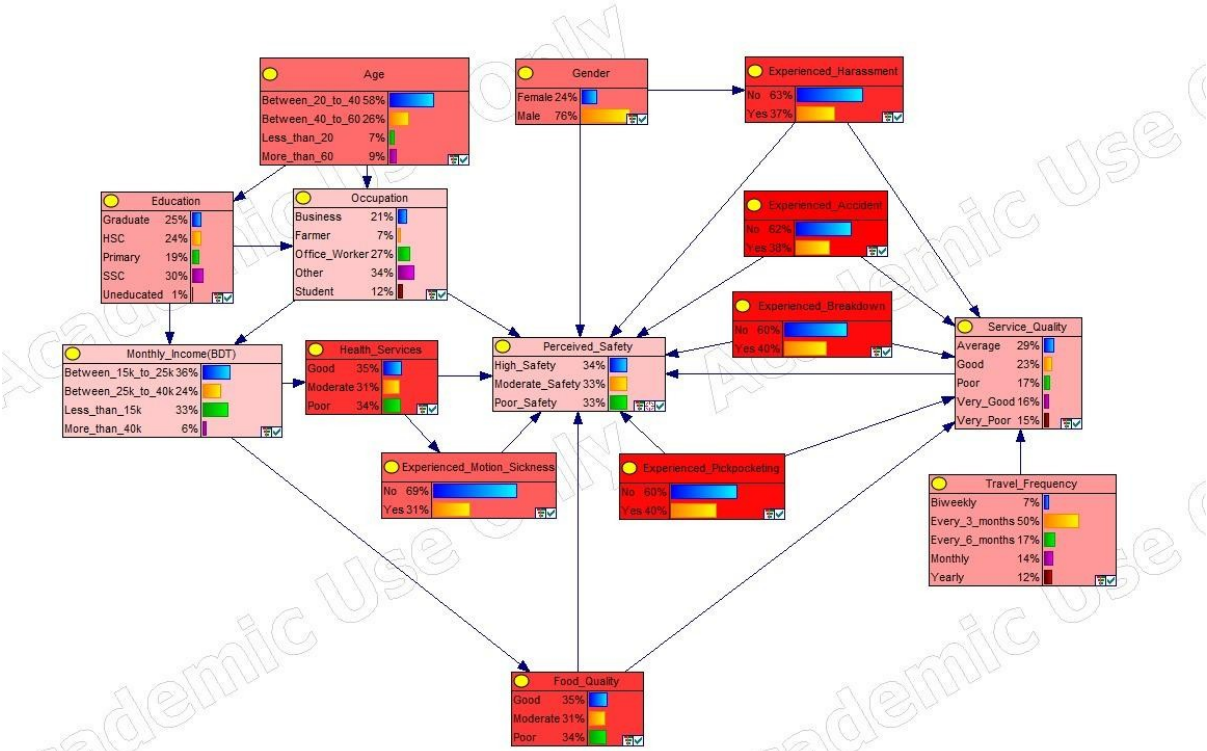

Figure 3: BBN with significant variables for the 'Perceived_Safety' node

4. RESULTS & DISCUSSIONS

Table 1 outlines the variations in marginal probabilities across different nodes for distinct scenarios with the 'Perceived_Safety' evidence. The marginal probability of a passenger experiencing good service quality decreases from 25% to 22%, if the evidence is set from 'High_Safety' to 'Poor_Safety' on the other hand the marginal probability of a passenger experiencing poor service quality increases from 16% to 18% in a similar change of evidence.

Similarly, the marginal probability of passengers' satisfaction with health services onboard decreases from 37% to 34% and their satisfaction with the food quality decreases from 37% to 34% if the evidence is changed from 'High_Safety' to 'Poor_Safety'. The marginal probability of passengers having a previous accident experience also increases from 37% to 39% while that of encountering an engine breakdown shifts from 39% to 41%. Probabilities of earlier experience with pickpocketing and

motion sickness both increase from 39% to 41% and 30% to 32%, respectively in similar changes to the evidence.

As shown in Table 1, variations in marginal probabilities are also noticeable across education level, monthly income, occupation, and travel frequency under the three categories of evidence.

Table 1: Marginal probabilities for all evidence of the 'Perceived_Safety' node

Attribute	Attribute Category	Evidence		
		High Perceived Safety	**Moderate Perceived Safety**	**Poor Perceived Safety**
Age	a. Less than 20	7	7	7
	b. Between 20 to 40	58	58	58
	c. Between 40 to 60	26	26	26
	d. More than 60	9	9	9
Gender	a. Male	76	76	76
	b. Female	24	24	24
Education	a. Uneducated	1	1	1
	b. Primary	19	19	19
	c. SSC	30	30	30
	d. HSC	24	24	24
	e. Graduate	25	25	26
Monthly Income	a. Less than 15k	34	33	32
	b. Between 15k to 25k	36	37	36
	c. Between 25k to 40k	24	24	25
	d. More than 40k	6	6	6
Occupation	a. Business	20	21	21
	b. Farmer	7	7	7
	c. Office Worker	27	27	27
	d. Student	12	11	12
	e. Other	35	34	34
Travel Frequency	a. Biweekly	7	7	7
	b. Monthly	14	14	14
	c. Every 3 Months	50	51	50
	d. Every 6 Months	17	17	17
	e. Yearly	12	11	12
Experienced Accident	a. Yes	37	37	39
	b. No	63	63	61
	a. Yes	36	37	37

Attribute	Attribute Category	Evidence		
		High Perceived Safety	**Moderate Perceived Safety**	**Poor Perceived Safety**
Experienced Harassment	b. No	64	63	63
Experienced Breakdown	a. Yes	39	40	41
	b. No	61	60	59
Experienced Pickpocketing	a. Yes	39	41	41
	b. No	61	59	59
Experienced Motion Sickness	a. Yes	30	30	32
	b. No	70	70	68
Service Quality	a. Very Poor	15	15	16
	b. Poor	16	17	18
	c. Average	28	30	29
	d. Good	25	23	22
	e. Very Good	16	15	15
Health Services	a. Good	37	34	34
	b. Moderate	31	32	31
	c. Poor	33	33	35
Food Quality	a. Good	37	34	34
	b. Moderate	31	32	31
	c. Poor	33	33	35

The BBN analysis reveals that the transition from a 'High_Safety' perception to a 'Poor_Safety' perception is associated with a decline in the marginal probability of passengers experiencing good service quality, coupled with a corresponding rise in the probability of encountering poor service quality. This means that service quality can have a significant effect on perceived safety. This perfectly aligns with the findings of previous studies (Nguyen-Phuoc et al., 2021; Shiwakoti et al. 2022). A well-maintained and efficiently run ship is perceived as more trustworthy, and passengers feel more secure when the crew demonstrates attention to detail in all aspects, including safety protocols. The overall positive experience with onboard services contributes to a favourable perception of safety. Thus, implementing a comprehensive safety training program for ship crews, focusing on meticulous adherence to safety protocols and efficient service delivery, could enhance passengers' perceptions of safety.

Results also show that when passengers perceive poor safety on the vessel, satisfaction with onboard health services and food quality decreases. This indicates that passenger safety perception is influenced by the presence of sufficient onboard health services, which affects confidence in the overall well-being support provided by the ship. Inadequate food quality can raise concerns about safety and hygiene standards, further affecting safety perception. Addressing these issues requires implementing a policy to enhance and monitor onboard health and food safety regularly. This involves rigorous training for onboard medical and culinary teams, ensuring compliance with industry standards. To maintain high standards, regular health inspections, certifications, and customer feedback mechanisms are recommended.

Based on the analysis, passengers who have experienced unpleasant incidents such as accidents, breakdowns, motion sickness, harassment, and pickpocketing in the past are more likely to have negative perceptions of safety. The underlying justification for this phenomenon could be attributed to the notion that prior interactions with distressing incidents have a profound influence on passengers' mindsets. If individuals have gone through a distressing situation in the past, it often creates a long-lasting effect. This can make them more sensitive or anxious about safety during travel. Even in objectively safe situations, the memory of past trauma can make them feel more cautious or worried. Vidmar & Perkovič (2015) and Regehr, et al. (2007) found similar evidence where one's perception of safety is influenced by their past interactions with a specific event. Incorporating educational or informative materials about the cruise's safety measures and statistics on incident prevention may help alleviate anxieties stemming from past experiences, fostering a more secure environment for all passengers. Creation and enforcement of strict laws for safety regulations and regular equipment inspections can decrease the number of accidents and breakdowns while employing sufficient quantities of well-trained security personnel can reduce the number of pickpocketing incidents. Over time, this approach has the potential to significantly diminish the occurrence of negative passenger experiences, ultimately fostering a positive perception of the ship's safety standards.

5. CONCLUSIONS

Bangladesh's Inland Water Transport System (IWTS) remains a popular mode of travel due to its extensive waterway connections. However, the unfortunate neglect of passenger safety, particularly in considering their perceptions, presents a significant and concerning challenge. Acknowledging the gravity of this issue is imperative, as it directly influences the trust and confidence of passengers. Our findings underscore the need for prompt action by authorities to address these concerns, thereby enhancing passenger safety and reinforcing public trust in the IWTS. Through direct interviews with 260 passengers, we accurately gauged the overall perception of safety among the respondents. To evaluate this data precisely, the Bayesian Believe Network (BBN) analysis using the PC algorithm was chosen. By doing so, the study overcame the drawbacks of traditional regression analysis. Through the exploration of interdependencies among the predictor variables, the BBN analysis aided in exploring the effect of passengers' socioeconomic demographics, travel patterns, and safety concerns on their perception of safety. Furthermore, a sensitivity analysis was done by using the "Leave one out" method. The study revealed that satisfaction with health services, food quality, and overall service quality stand out as noteworthy contributors to a passenger's perceived safety.

Additionally, experiences involving accidents, harassment, engine breakdowns, and pickpocketing exert a substantial influence on the perceived safety of passengers. To tackle these issues, suggested solutions involve thorough training for the ship's crew, security personnel, medical staff, and culinary teams. Additionally, regular monitoring, and inspections for health, food and safety standards, along with customer feedback, contribute to enhancing overall safety measures. By addressing these adjustments, policymakers and ship owners can enhance safety measures while minimizing fatalities and injuries, thereby improving the overall quality of service. This will also ensure that the IWTS not only continues to thrive but also becomes a safer and more reassuring mode of transportation, prioritising the well-being and satisfaction of its passengers.

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