A STUDY TO ASSESS THE SAFETY ASPECTS AND MARINE TRAFFIC CONGESTION AT KARNAFPHILI CHANNEL

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ABSTRACT

Chittagong Port is the principal seaport of Bangladesh which is located on the bank of the Karnaphuli river. The river is approximately 50 km long from Kaptai Dam to the Halda-Karnaphuli confluence, and 30 km long from the Halda-Karnaphuli confluence to BN Academy. The safety issues and the change in maritime traffic congestion have been studied if a new port is planned at the upstream of the channel. Chittagong Port Authority has taken an initiative to build a new lighterage jetty at Hamid Char where safety is of vital issue for the safe navigation of the vessel to and from the Bay of Bengal. At present, small wooden trawlers, steel trawlers, and small wooden boats make up the majority of the vessels that pass through the channel near Hamid Char. According to the study when a new port will be opened, if the average vessel traffic per hour increases by 1, traffic congestion will rise by 12.05%. Additionally, the probability of death is currently 8 in 10^6 in the Hamid Char region and 9 in 10^6 in the area close to the Chittagong port. The Predicted increase in traffic volume brought on by the operation of a new port, this risk will increase in the future.

Keywords: river channel safety, marine traffic congestion, Karnaphuli river, new port

1. INTRODUCTION

Ships and vessels are one of the most important tools in global trade and economy. About 70 % of the world’s commodities are transported through ships including container vessels, oil tankers, cargo vessels, etc. The scenario is also the same for a riverine country like Bangladesh. Chittagong Port is the main seaport of Bangladesh. It is situated in the banks of the Karnaphuli river and handles over 90 percent of Bangladesh's export-import trade, [1]. It is used by India, Nepal, and Bhutan for transhipment. [2] [3]. In 2019 it was the 58th busiest container port in the world [4].

The present container traffic growth in Chittagong Port is almost double as compared to the prevailing GDP of Bangladesh [5]. Normally transport and GDP growth is considered to grow at par but in the least developing countries like India, Pakistan, Sri Lanka, and Bangladesh, containerization was a late starter as such growth in nascent years has shown robust tendencies but once traffic has consolidated growth rate would taper off and would be more consistent with GDP rate. The present high berth occupancy and the projected growth of traffic particularly containerized cargo through the port of Chittagong has underscored the urgent need for improving the port's throughput capacity or constructing new ports or berths to match the needs not only of the expected increase in the traffic but also of the growing trend of transporting cargos through ships. Chittagong Port Authority (CPA) plans the following ongoing and future – as medium-term projects to enhance the container handling capacity [6]. On-going Projects are:

1 Feasibility study and Design for Construction of Karnaphuli Container Terminal (KCIT)
2 Strategic Master Plan for Chittagong Port by ADB’s Technical Assistance (TA)

The up-coming Projects as Short-Term Plans are:

1 Construction of Laldia Bulk terminal under Public Private Partnership (PPP)
2 Construction of Karnaphuli Container Terminal (KCT) at jetty 10, 11, 12 & 13
3 Construction of Lighterage Jetty and Service Jetty on the bank of Karnaphuli River near Hamid Char
4 The Chittagong Bay Terminal
The current study focuses on the safety aspects of the Karnaphuli channel if a new lighterage jetty is constructed near the Hamid Char region. The proposed location is approx. 25 KM upstream from the Bay of Bengal. Hence, the river traffic condition will change drastically due to the movement of new vessels to and from the Bay of Bengal in this new lighterage jetty.

2. LITERATURE REVIEW

Ships are designed to travel as efficiently as possible from port to port, mainly via open sea and their design focuses on carrying the maximum amount of cargo whilst reducing drag and lowering fuel consumption, using streamlined underwater forms that include bulbous bows and stern transoms. However, once they enter shallow, laterally confined access channels they begin operating in an environment for which they have not been optimally designed. This can give rise to problems in ship handling and higher squat values which can reduce under-keel clearance (UKC) and safety. Channel designers, port authorities, and operators need to decide how to manage these trends to remain competitive in the global market while still ensuring safe port/jetty operations. Approximately 70 to 80% of maritime accidents are caused by human error [7]. The remainder is caused by mechanical breakdowns of ship or tug equipment (i.e., engines and steering gear) and by the channel itself (i.e., lack of proper maintenance of channel dimensions).

By using the marine traffic assessment index, Young-Soo Park et al. [8] assessed the danger of excursion ship operations at Busan North Port and looked into the viability of such activities. Busan North Port's traffic flow, marine accidents, and port status were examined for this reason. The risk and likelihood of excursion ship operations in Busan North Port were also evaluated using marine traffic assessment indexes, including, risk analysis using ES Model, traffic congestion, and IWRAP MkII, a maritime risk assessment tool. This study can be utilized as a starting point for examining the risk factors that might arise when the conventional and container harbor traffic volumes are moved to the New Port built in the Busan River and the operation of the old North Port is changed.

Deug-Bong Kim et al. [9] applied regression analysis to evaluate the impact of hourly average congestion calculated by a bumper model in the congested area of each passage of each port on the peak time congestion, to suggest the model formula that can predict the peak time congestion in Korea. They conducted a regression analysis of hourly average congestion and peak time congestion based on the Automated Identification System (AIS) survey study of 20 ports in Korea. As a result of the analysis, it was found that the hourly average congestion has a significant impact on the peak time congestion and the prediction model formula was derived. This formula developed in the paper can be used to calculate the peak time congestion based on the predicted hourly average congestion. These works were conducted for the Korean rivers. No similar works are found to assess the marine traffic condition of one of the most important channels in Bangladesh, Karnaphuli Channel. According to Zobair et al. [10], passenger and cargo-carrying vessels encounter more collisions than any other type of vessel. In another article by Awal, Islam, and Hoque [11], a geographical information system (GIS) based analysis of accident locations was carried out. According to the authors, the southern part of Bangladesh is the most hazardous location, and the waterway along the Meghna River appears the route to be concerned with. The study also identified the accident locations centered along the waterways of Dhaka and Narayanganj districts of Bangladesh. But in his research, marine traffic or probable accidents in Karnaphuli channel was not covered.

Therefore, in this paper, a safety assessment has been performed concerning the maritime traffic congestion along the Karnaphuli channel, positioned within the territory of the busy commercial port hub–Chattogram, located in the southeastern part of Bangladesh. The marine traffic assessment index i.e., traffic congestion is used in this study to analyze the risk and change in marine traffic patterns due to the inclusion of new ships in the channel from the Bay of Bengal. According to PIANC [12] channel depth, turning basin width, bending, and operational limits i.e., the number of vessels to run across the channel, vessel dimensions, etc. are important aspects to be considered while designing a jetty in a channel. The current study addresses these features to design a new lighterage jetty at Hamid Char.

3. GEOLOGICAL DETAILS OF THE BERTH LOCATION PROPOSED IN THIS STUDY

Karnaphuli is a tidal river having semi-diurnal characteristics. During the flood period, the flow travels a long distance in the upstream direction of Halda river and very near to Kaptai Dam in the upper Karnaphuli river. The length of the Karnaphuli river is around 80 km starting from Kaptai Dam to BN Academy at Patenga. The width of the river varies from 500 m to 1.1 km having an average width of around 700 m. The minimum water depth during the lowest Spring tide varies from 1m to 14 m along the river, having an average water depth of around 6m – 7m. The proposed Hamid Char Jetty site is located on the right bank of the Karnaphuli river which is around 2.5 km downstream of Kalurghat bridge (Figure 1). CPA conducts topography, bathymetry, and hydrography survey of the Karnaphuli River every year.
The bathymetry contour map of the water depth (with respect to ISLWL – Indian Spring Low Water Level) during the month of October 2015 at the vicinity of the proposed Hamid Char Jetty site has been presented in Figure 3. The proposed jetty is tentatively placed in this figure. From this contour map, it is seen that the width of the river varies from 980m to 1050m, and the least water site.

4. METHODOLOGY
The following specific steps have been followed to carry out this study:
1. Collection of bathymetric data of Karnaphuli river from upstream (Hamid Char Area) to downstream (CPA). Study the tide, current, and geological characteristics of the Karnaphuli Channel.
2. Traffic survey of the existing vessels for carrying out inland traffic flow analysis.
3. Determination of vessel size by considering physical constraints (along the channel of the proposed area at Hamid Char) such as air draft of Shah Amanat bridge/ Kalurghat Bridge during highest and lowest tide levels and location of mooring buoys as well as available data mentioned above.
4. Assessing the traffic congestion possibility due to the change in vessels movement.
5. Determining the risk factors along with risk mitigation suggestions due to the increased traffic flow.
5. DIFFERENT ASPECTS AND SAFETY FEATURES NEEDED FOR THE TENTATIVE LIGHTERAGE JETTY

5.1 Dimension and Capacities
Designing a new berth/jetty at a channel is a challenging task. It requires multiple parameters to take into consideration for safe operation. The World Association for Waterborne Transport Infrastructure (PIANC) has specific guidelines and rules to design jetties at a channel. Since, Karnaphuli channel is one of the most important channels in Bangladesh, constructing new jetties or berths there needs special care and considerations. Most of the international trades of the country are conducted through the Chittagong Port which is situated in this channel. The Chittagong Port Authority (CPA) has their own rules and regulations to maintain safe operations in the channel. According to CPA website maximum permissible draft and length of vessel for entering and leaving Chittagong Port berth is 9.50 meters and 190m respectively. Though CPA maintains the guaranteed navigational depth of 9.5m till the port location, the scenario changes radically in the upstream of the river specially at the portion beyond the Shah Amanat Bridge. The average water draft at the upstream region beyond the Shah Amanat Brige is 4.5m (Figure 3). The Hamid Char region at the upstream of the bridge is comparatively less congested and large open area to develop a new jetty or berth to meet the future need of national and international maritime transportation system.

In this study Hamid Char region has been proposed to use as a tentative zone to construct a new lighterage jetty or berth. As per PIANC guidelines the width of the channel, maximum allowable water draft and vessel length, jetty throughput capacity, turning basin width, bend of the river bank, etc. are important factors to be considered while constructing a new jetty to ensure a safe navigation system along the channel.

Current study has been conducted considering the limitation of Shah Amanat Bridge, the river navigational depth, draft restrictions implemented by the Chattogram Port Authority (CPA), and the guidelines set by PIANC.

Considering a lighterage jetty the vessel’s Length Over All (LOA) and the Breadth is assumed as 90 meters and 11–14 meters respectively. The vessel capacity is estimated to be 2000 tons having a draft of around 5 meters. Considering different factors (tide, vessel depth, drat etc.), the jetty face elevation will be nearly 6.5 meters, CD (ISLWL). The following cases have also been considered to determine the projected jetty elevation:

- Karnaphuli river flood danger level
- 100 years of sea level rise
- 100 years of land inundation
- Highest tide level at Karnaphuli river

5.2 Channel Width
According to the PIANC the required width of a channel for safe operation of vessels is calculated using the following formulas [12]:

Channel Width, \( W = 2 \left( W_{BM} + \sum W_i + W_B \right) + W_P \)  \( \)  \( \)  \( (1) \)

Channel Width, \( W = (W_{BM} + \sum W_i + 2* W_B) \)  \( \)  \( \)  \( (2) \)

where,
- Basic Width = \( W_{BM} \)
- Additional Width = \( W_i \)
- Separation Distance = \( W_P \)
- Bank Clearance = \( W_B \)

The channel width infront of the Chittagong Port is approx. 600m and the widest vessels that can enter the channel to Chittagong Port is 32m. And for the Hamid Char Port, considering lighterage vessels the breadth (B) will be within 11~14 m. The most critical zone is Shah Amanat Bridge Area, especially the distance between the Bridge Pier. The pier-to-pier distance of Shah Amanat Bridge is 200 m. So, this distance is a major hindrance to the widest vessel that can safely operate in the Hamid char port region. Here two separate cases are considered. Firstly, a two-way traffic system is taken into consideration where two vessels will operate safely between two piers and the equation is the same as (1). Using that formula, the required minimum width is as follows:

Channel Width, \( W = 2 \left( W_{BM} + \sum W_i + W_B \right) + W_P \)  \( \)  \( \)  \( = 165.2 \text{ m} \)

So, the required channel width to safely operate the new lighterage vessels having 14m width using two-way traffic system is within the range of the available space of bridge piers. Now, for a one-way traffic system where one vessel will operate between two piers, formula (2) is applied:

Channel Width, \( W = (W_{BM} + \sum W_i + 2* W_B) \)  \( \)  \( \)  \( = 81.2 \text{ m} \)

So, in this case, also the required width is within the available bridge pier space with more safety limits than the two-way system. However, it will be safer to operate one vessel between two piers and use two separate piers spacing for two individual vessels.
5.3 Turning Basin Width

The basin width near the Chittagong Port is approx. 600m. The max river width required to turn a vessel without a tug is approximately 380m for the Chittagong Port region. For the Hamid Char region considering 90m long vessel the required turning zone is 180m. The width of the river in front of the jetty/berth is approximately 850m which satisfies the turning basin requirement of the vessel.

5.4 Depth

The depth of the approaching river, the depth near the berth, and the length of a basin depends upon the following factors:

- Draft of the ship
- Squat and trim allowance
- Vertical ship motion
- Net under keel clearance

As per the Chittagong Port Authority max draft of a vessel while entering and leaving the channel is 9.5m. CPA regularly conducts dredging operation to maintain the guaranteed depth of the channel. However, considering above safety features for safe navigation of the lighterage vessels of the proposed jetty at Hamid Char, the channel must maintain at least 6.3m depth.

6. CHANNEL TRAFFIC CONDITION AND RISK SCENARIO

6.1 Traffic Condition current and future perspective

The marine traffic congestion using the bumper mode [13] is found by comparing the practical traffic volume that can be accommodated by the passage and the actual marine traffic volume. In other words, the number of vessels entering or departing the port in the present or the future is surveyed to estimate the traffic volume ($Q_T$) and compared with the practical traffic volume that can be accommodated by the passage ($Q_p$) to assess the traffic congestion ($T_c$). Traffic congestion is acquired by dividing the traffic volume based on the traffic survey by practical traffic volume and converting the quotient into percentages as shown in the following formula [13]:

$$T_c = \frac{Q_T}{Q_p}$$

(3)

In the current situation, most of the vessels that travel through the channel near Hamid Char are steel trawlers, small wooden trawlers, and small wooden boats. Small wooden trawlers and small wooden boats have little significance on the traffic of the main channel of the river. Therefore, in the current projections and survey steel trawlers and ships are considered only. As per the survey conducted (Figure 4) by the authors, steel trawlers/ships that run through the channel vary between 7-11 Nos/hour. For the assessment, an average of 8 steel trawlers/vessels have been considered per hour at current condition.

If the average vessel number per hour is increased by 1 when the port is in operation the traffic congestion will increase by 12.05% which is calculated using the formula of equation-3. As per the projected jetty throughput capacity found by the CPA authority considering 2000 tons vessel 1 No. ship/2hr will run through the channel when the new berths will come into operation. Hence, the traffic congestion will be lower than 12.05%. Moreover, when the average vessel per hour will be increased by 2, the traffic congestion in the channel will increase by 24.1%. Figure 4 shows the change in traffic congestion with increasing number of new vessels that may run through the channel.

![Figure 4: Vessel traffic data (No of vessel/hr) from the survey conducted by the authors](image-url)
In addition to the above recommendations, some mooring buoys in the central line of the channel near Chittagong Port need to be relocated or eliminated to get free passage into the channel. In figure 5, 6 and 7 some mooring buoys are shown in the mid portion of the channel. In future, when the vessel movement will increase due to the construction of new jetty the buoys shown in the above-mentioned figures will hinder the free movement and cause trouble in safe maneuvering of the vessels. Hence, to avoid increased traffic congestion the following buoys, listed, need to be relocated or to be removed for safe navigation to Hamid Char Port:

Buoy-1, Buoy-2, Buoy-3, Buoy-8, Buoy-9, Buoy-10, Buoy-11, Buoy-12, Buoy-13, Buoy-14, Buoy-15, Buoy-16.

![Figure 5: Change in traffic congestion with increasing number of vessels per hour](image)

**6.2 Risk Scenario**

To assess the risk associated with vessel operations in the channel, two different zones have been considered. One is upstream of the channel near Hamid Char and another one is downstream near Chittagong port. According to the PIANC’s guideline [12] for approach channel design the risk assessment should include the frequency of incidents (grounding, collision, stranding, etc.) and the casualties due to those incidents. The current risk to life in the Hamid Char region is 8 in $10^6$ and 9 in $10^6$ near the Chittagong port region. To calculates risk, 2005-2015 years’ accident data [14] in the channel has been taken into consideration. This risk will be increased because in future the traffic intensity will increase during the operation of the new port as stated earlier. Based on the guideline of PIANC the risk should be 1 in $10^6$. As the current risk is higher than the suggested value following steps should be taken to alleviate the risk and maintain the risk within the suggested value. However, the port authority already installed VTMS, which will help reduce accidents in the channel.

1. Operation Limits (maximum no of vessels that can enter at a time in the channel)
2. Rules of Operation (types of vessels that can operate simultaneously in the channel)
3. Aids to Navigation (marker buoy, lighting system, flags, etc.)
4. Traffic Separation Schemes: A traffic separation system (or "TSS") is a section of water where ship travel is strictly controlled. It is often formed in areas where there are numerous ship movements, numerous vessels traveling in opposite directions, and/or where there is a significant risk of collisions.

![Figure 5: Buoy Location – 1](image)

![Figure 6: Buoy Location – 2](image)

![Figure 7: Buoy Location – 3](image)
7. ACKNOWLEDGMENTS
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8. CONCLUSION
In the current study the safety aspects of the Karnaphuli channel in respect to lighterage vessels (capacity upto 2000 tons) has been assessed. The channel width, channel depth, turning basin width, allowable vessel dimensions, etc. has been considered as part of the safety features of the channel. Based on above discussions channel width, channel depth, turning basin width meet the standard values required as per PIANC’s guideline. However, when new jetty will come in operation the number of vessels that will run through the channel will increase accordingly. This will increase traffic congestion along with the risk of accidents in the channel. As safety, aspects are of vital importance for safe operation of a channel. Innovative solutions are needed to reduce the risk percentage that may arise while a new jetty or port will come in operation in the Karnaphuli channel.

REFERENCES