ANALYZING DREDGING QUANTITIES FOR SUSTAINABLE WATERWAY MANAGEMENT: A CASE STUDY OF MAWA TO ARICHA ROUTE

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ABSTRACT

Bangladesh's vital water transportation routes, like the MAWA to ARICHA corridor spanning 70.50 kilometers, are essential for the nation's economic well-being. However, the deposition of sediment every year along this route poses a significant challenge for navigability. This study aims to analyze sedimentation characteristics, patterns, estimate sediment quantities, and develop a comprehensive dredging plan to remove this sediment for sustainable waterway management. In order to do this, first data for dredging related of this route were collected from the Bangladesh Inland Water Transport Authority (BIWTA) for the years 2019 and 2021, which later supplemented with information from the US Geological Survey (USGS) website. Using Geographic Information System (GIS) tools, particularly ArcGIS, this route was model, using data visualization technique, creating detailed route maps, highlighting water depth variations over the two years. From the model analysis volume sediment was calculated. The amount of volume sediment was found to be 3.03×10^5 cubic meters and compared with available published sedimentation rate and found satisfactory. This enabled to estimate the annual quantity of dredged material. Subsequently, some studies were performed to choose suitable dredgers and pumps, considering dredging capacity and efficiency. Based on sediment quantities, a 16 inch cutter suction dredger was selected and furthermore an optimal dredging plan was proposed. The proposed dredging plan was consideded based on the sedimentation rate, dredger capacity, and pump flow rate, which ensures efficient removal of accumulated material, preserving the route's navigability and economic significance. The research yields invaluable insights into sedimentation rates and dredge quantities for the MAWA to ARICHA route. Based on the conducted study, several decision-making can be applied in other waterway managements. Moreover, the proposed dredging plan can serve as a model for other routes, contributing to navigability and regional economic prosperity.

***Keywords**: Dredging quantities, mawa to aricha, the padma, bangladesh, navigability*

1. INTRODUCTION

Waterways have long served as crucial channels for transportation, trade, and overall economic development in numerous regions worldwide. They have become the cheapest means to transport and communications, providing a rich network of rivers, canals, creeks which crisscrossed the entire country. In some areas they are all that is needed for transportation. However, the effective management of these waterways remains in a challenge, particularly in the face of increasing industrial activities and environmental concerns. Dredging, a key process in waterway maintenance plays a vital role in ensuring navigability, mitigating flood risks, and sustaining aquatic ecosystems (Alam, A. M., 2023). The sustainable management of waterways demands a better understanding of the dredging quantities required and their impact on the surrounding environment.

The Padma River System is a 120 km long river. Every year, flooding occurs in some regions of these districts along the Padma River bank as a result of overtopping and breaching of flood control embankments. Faridpur Sadar and Char Bhadrason in the Faridpur district, as well as Harirampur in the Manikganj district, are significant examples of these localities, and the local populations of these places experience floods and erosion on a regular. The Padma has a mean annual discharge of 28,000 m3/s and bank full 3 discharges between 43,000 and 75,000 m3/s. The bed material is typically 0.10 mm in size. The river is still in its infancy in terms of geomorphology (Cunderlik, A., 2001). Sultana, P., et. al. (2017) discussed on Dredging and Land Reclamation in Bangladesh. They mentioned that Government of Bangladesh has undertaken many significant projects to make extensive use of rivers through dredging. However, the Government’s plans and projects of dredging should be directed not only towards improvement of the navigability but also to acquire new land through land reclamation in order to fulfil the increasing demand of land requirement due to rapid population growth.

The main objectives of this study are, to analyse Mawa to Aricha navigational route for dredging purpose, to analyse the depth of water of this route, to create a geographical map of MAWA to ARICHA navigational route using ArcGIS, to construct 3D modelling of the route using ArcScene, to provide volumetric calculation of dredged material to create a dredging plan.

This paper presents a comprehensive analysis of dredging quantities within the context of sustainable waterway management, focusing on the Mawa to Aricha route—a critical waterway in the context of Bangladesh. The Mawa to Aricha route, situated along the Padma River, stands as a lifeline for the transportation of goods and people, connecting numerous regions and facilitating trade within the country. However, the rapid sedimentation and increasing commercial activities along this route have intensified the need for effective dredging practices to ensure its continued functionality and environmental sustainability.

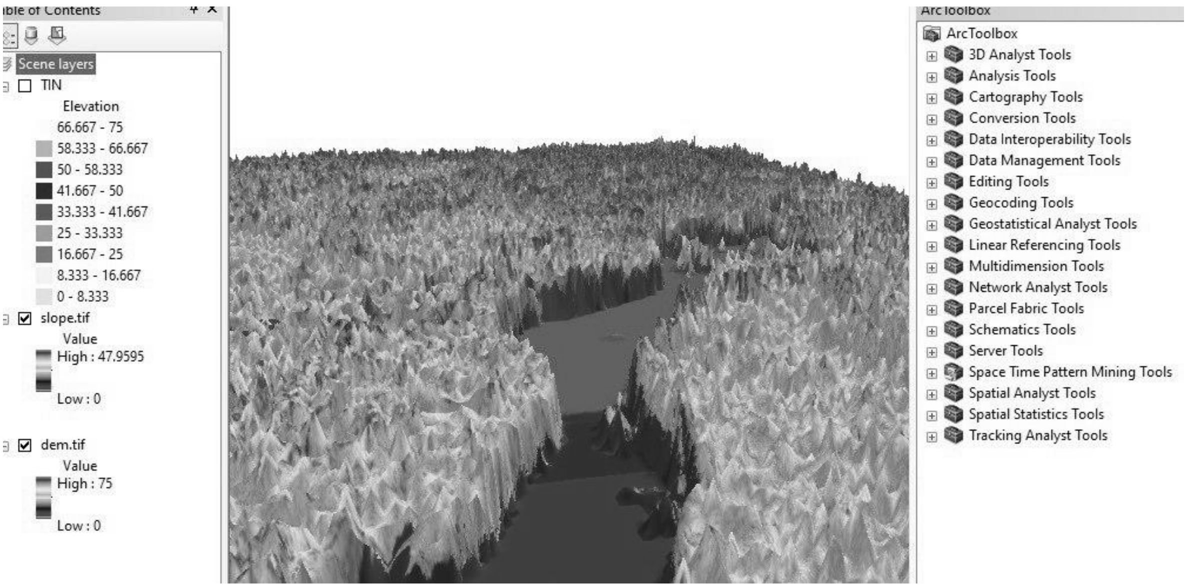
2. METHODOLOGY

The methodology of this work starts with the selection of this navigational route Mawa to Aricha. Then the route mapped with the google earth pro. Simultaneously data regarding to bathymetry, bed elevation, sedimentation, etc. from Bangladesh Inland Water Transport Authority (BIWTA). The respective data was analysed using ArcGIS software. The volumetric calculation of soil sedimentation as a reservoir was done. The sedimentation volume was calculated for two years 2019 and 2021. After that, the volume of the material to be dredged was calculated. Furthermore, a dredging plan is proposed for different dredgers of various capacity.

2.1. Plotting in Google Earth Pro

KML file was generated from Shp file and imported in Earth Pro and explained in Figure 1. Then it was cross checked for the actual navigational route whose volume is to be calculated. From that, the elevation of water level was found. A layer in ArcScene was created. In this layer, DEM data was the input data. The DEM data was needed for creating 3D model. These data were obtained from the website USGS. By creating an account. After downloading the Dem data, the input was given into ArcScene where a layer already has been created. Then using 3D analyst tool, the Dem data was converted. The layer coordinate system was set to BUTM. Then, we need to set some layer property like Rendering, Symbology, display (cubic convolution for continuous data), Base Height, Vertical Exaggeration etc. Then the 3D view of the model was prepared and explained in Figure 2.

Figure 1: Plot of Mawa to Aricha route using Google Earth Pro



Figură 2: 3D view of the model (Mawa to Aricha route)

2.2. Data Collection and Volume Calculation

Data related to bathymetry, bed elevation, sedimentation and drawing of the Mawa to Aricha navigational route is collected from BIWTA. There were 11 sets of data for two years 2019 and 2021. These sets of data divided the Mawa ghat into some blocks. These data provide the information of latitude, longitude and elevation of the points situated in river bed (the format of the data is shown in Figure 3). Here under the sea level y axis is taken positive and above the sea level axis is taken negative. At first, the data was formatted into excel from text files. Then data was imported in ArcGIS and an Attribute table was created. The data display command and data export command was given for creating the shape file. Thus, the shape file was created. After that, shape file was imported to generate KML file and raster file Using tools (conversion tool, KML tool) 3D analyst tool used (point to raster). Surface volume was commanded to calculate volume. Thus, volume is considered from each set of data for each year. The coordinates and elevations are shown in Table 1The difference between the volumes of 2 years is found approximately 606707.00 cubic meters and describe in Table 2. The sedimentation rate was calculated 3.03 x 10^5 cubic meter per year which the materials to be dredged.

Table 1: Longitude, Latitude and Elevation

Points	**Longitude**	**Latitude**	**Elevation**
Set1	526925.00	2589400.00	3.10
Set2	526912.50	2589437.50	3.27
Set3	526925.00	2589437.50	7.55
Set4	526912.50	2589450.00	6.41
Set5	526925.00	2589450.00	7.92
Set6	526937.50	2589462.50	8.04
Set7	526925.00	2589425.00	5.67
Set 8	526937.50	2589387.50	4.28
Set9	526937.50	2589412.50	6.85
Set10	526937.50	2589400.00	6.38
Set11	526937.50	2589425.00	7.09
Set12	526950.00	2589400.00	6.67
Set 13	526950.00	2589437.50	7.67
Set 14	526937.50	2589437.50	7.70

In Bangladesh, total waterway of length 24140 km and every year, total 1655 x 10^5 cubic meters material need to be dredged. According to that, this present study route needs to be dredged on average 2.83 x 10^5 cubic meters (Ahmad, B., K., et. al 2010). Our calculation shows the required amount of materials to be dredged is 3.03x 10^5 cubic meters which is relatively higher than the average one 2.83 x 10^5.

Table 2: Volume Comparison

Data	2021 Volume (m^3)	2019 Volume (m^3)	Decrease Volume (m^3)
1747	3132922.65	3152678.57	19755.91
1748	329133.49	329343.47	209.96
1749	510700.31	511569.02	868.71
1789	7495289.06	7588092.39	92803.33
1790	243731.91	250569.55	6837.65
1791	2145554.38	2187553.89	41999.52
1807	7303221.09	7517249.73	214028.64
1808	63313.73	81245.56	17931.83
1820	3397294.61	3557597.44	160302.83
1821	168401.20	173221.67	8420.47
1828	1188908.14	1236056.42	47148.28
Total	**25978470.58**	**26585177.69**	**606707.12**

3.0 Mathematical Formulation

These are the equations used for calculations in this paper.

$$P_t = f_m \times hp_d \quad (1)$$

$$P_{nom} = f_f \times P_t = f_f \times f_m \times hp_d \quad (2)$$

$$f_p = \frac{1}{1 + \frac{P_{nom} \times t_p}{z \times p \times b}} \quad (3)$$

$$f_a = \frac{1}{1 + \frac{P_{nom} \times t_p \times f_p}{z \times p \times b}} \quad (4)$$

$$P_{\max} = f_a \times f_p \times P_{nom} \quad (5)$$

$$V = \frac{Q \times 0.4085}{64} = \frac{1622.68 \times 0.4085}{64} \quad (6)$$

$$V_L = F_L \sqrt{2 \times g \times D \times \frac{S - Sl}{Sl}} = 1.04\sqrt{2 \times 32.2 \times (8/12) \times (2.65 - 1)/1} \quad (7)$$

4.0 Results and Discussion

4.1 Estimation of dredger output

After the amount volume of dredged materials found, the dredger was selected. The type of the dredger is chosen as Cutter Suction Dredger (CSD). Later on, the required power to drive the dredge pump (hp_d) is calculated (Bray R. N. 1995) which is about 2000 horse power for discharging sedimentation at a distance of 1.5 kilometres, modification factor (f_m) is taken 0.52. Thus, theoretical output (P_t) calculated as 1040 cubic meters per hour (Eq^n 1). After that, factor(f_f) is taken 0.7 for various dredging depth and face heights. The reduction in theoretical output (P_{norm}) (Eq^n 2) 728 cubic meters per hour. is calculated. Delay factor (f_p) ((Eq^n 3) and additional delay (f_a) ((Eq^n 4) are calculated 0.6788 and 0.9291 respectively. Finally maximum potential output (P_{max}) ((Eq^n 5) is calculated 459.18 cubic meters per hour.

4.2 Typical Pump Calculation

Taking specific gravity 2.65 and average particle size 0.1 millimetre, the slurry mixture velocity is calculated 10. 357 feet per second ((Eq^n 6) which is compared with minimum settling velocity; 8.75 feet per second using Durand's equation ((Eq^n 7). Since the slurry mixture velocity is greater than limiting settling velocity, 8-inch pipe diameter is suitable.

4.3 Sample Calculation and Planning for Dredgers

Letting,
Average working hour for a dredger - 5 to 7 hours
Element of sediment- Clay, silt & sand Type
Dredger capacity-500 cubic meter/hour

Total dredging hour =3.03X105/500 = 606-hour s

No. of days for a dredger (6 hours working/day) =606/6 =101 days
A dredger needs to work for 101 days if its working hour is 6
5 dredgers can do it in 20 days.

After considering the cycle factor, modification factor and time delay factor,
Average working hour for a dredger - 6 hours
Element of sediment- Clay, slit & sand Type
Dredger capacity-461.61 cubic meter/hour
Total dredging hour =3.03X105/459.18 = 660 hour s

No. of days for a dredger (6 hours working/day) =660/6 = 110 days
A dredger needs to work for 110 days if its working hour is 6
For considering more predictions of more working days, same steps are followed and shown in Table 4.

Table 3: Days required for a dredger according to diameter

Dredger Diameter	Output (m3/hr)	Days required for a dredger
10 inch	459.18	110 days
20 inch	862.11	59 days
24 inch	1212.99	40 days

Table 4: Comparison between Estimated and Calculated materials to be dredged quantities

Name	Length (km)	Dredging required (Lacs m^3)
Total waterway	24140	1655.1

Our study route	40.46	3.03 (calculated)
Our study route	40.46	2.83estimated)

5. CONCLUSIONS

In the course of this comprehensive study, we selected the route of MAWA to ARICHA. The length of this route is about 70.50 kilometers. Our primary objective was to analyze the dredged material that is annually deposited along the critical MAWA to ARICHA route. To achieve this, an extensive array of data was required, which we diligently collected from the Bangladesh Inland Water Transport Authority (BIWTA) spanning two years, namely 2019 and 2021. The core analysis heavily relied on the powerful Geographic Information System (GIS) tool, ArcGIS, which allowed us to effectively process and visualize the collected data. Through this tool, we created detailed route maps that depicted the variations in depths between the two years under study. By focusing on the parameter of volume, we conducted a meticulous comparison that ultimately enabled us to ascertain the sedimentation rate. The volume of 2021 and 2019 were 2.59x107 cubic meters and 2.65x107 cubic meters.

Having accurately determined the sedimentation rate which is 3.03x105 cubic meters, we could then estimate the quantity of dredge material that accumulates annually. In our country, yearly required dredging according to BIWTA is about 1655.1X105 m3. The total navigable route length is 24140km. As a result, the average sedimentation rate for our route is about 2.83X105 m3. Subsequently, our attention shifted towards identifying the most appropriate dredgers for this specific dredging task. This process involved numerous trial and error experiments to determine the dredger with the necessary capacity to effectively remove the accumulated sediment.

we selected a cutter suction dredger. we evaluated and selected a suitable pump whose maximum capacity is 1622 gpm, to facilitate the efficient removal of the dredged material. This type of dredger needs to work for 110 days if its working hour is 6 and five dredgers can do it in 22 days. The probable dredging hours depend on the model of dredger.

Our research has yielded invaluable insights into the sedimentation rates and dredge quantities along the Mawa to Aricha route. The results obtained from this study holds significant importance, as the selected navigational route plays a pivotal role in our nation's economy. This comprehensive plan considers the sedimentation rate, dredger capacity, and pump velocity to ensure the successful removal of the accumulated material, thereby maintaining the navigability and economic viability of this vital transportation pathway.

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