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Review Article

Application of Artificial Intelligence (AI) in Dredging Efficiency in Bangladesh

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Abstract: The integration of Artificial Intelligence (AI) into the dredging systems and dredging machinery used in "capital" and "maintenance" dredging in Bangladesh can enhance the efficiency of the machines and dredging process, enabling the operators to perform regular and repetitive dredging tasks safely in the rivers, ports, and estuaries all over the country. AI, including Big Data, Machine Learning, Internet of Thing, Blockchain and Sensors and Simulators with their catalytic potentials, can systematically compile and evaluate specific data collected from different sources, develop applications or simulators, connect the stakeholders on a virtual platform, store lakes of information without compromising their intellectual rights, predicting models to harness the challenges, minimise the cost of dredging, identify possible threats and help protect the already dredged areas by giving timely signals for further maintenance. Furthermore, the application of AI modulated dredging devices and machinery can play a significant role when monitoring aspects becomes crucial, keeping environmental impacts mitigated without affecting the quality of the human environment. This study includes the evaluation of the application of AI – its prospect and challenges in the existing dredging systems in Bangladesh against the backdrop of the challenges faced in capital and maintenance dredging in the major rivers – and assess whether such inclusion of AI is likely to minimise the cost of dredging in the rivers of Bangladesh and facilitate the materialisation of the objectives of Bangladesh Delta Plan 2100.This paper studies the organisation's infrastructural requirement for the integration of AI into dredging systems, using benchmarking such as 1- "Understanding AI Ready Approach", 2-"Strategies for Implementing AI", 3-"Data Management", 4-"Creating AI Literate Workforce and Upskilling", and 5-"Identifying Threats" concerning the management and dredging operations of Bangladesh Inland Water Transport Authority (BIWTA), under Bangladesh Ministry of Shipping and Bangladesh Water Development Board (BWDB). The paper also uses several case studies such as channel dredging to show that the use of AI can bring a significant change in the dredging operations both in reducing the cost of dredging and in terms of harnessing the barriers in adaptive management and environmental impacts.

Keywords: ***Artificial Intelligence; AI Ready Approach; Bangladesh Delta Plan 2100; Big Data; Blockchain; Capital and Maintenance Dredging; Harnessing the Challenges; IoT; Implementing AI; Reducing Cost; Simulators; Upskilling***

1. Introduction

Dredging is a kind of default setting for Bangladesh, and the country cannot compromise it or replicate, alter, avoid or stop it. However, if "grasped timely" [1] into the existing systems of dredging in Bangladesh holistically, Artificial Intelligence (AI), with its catalytic potentials, can make the dredging machines and dredging systems automated, faster, efficient, and reliable, mapping out the present and the future of business [1] and resulting in significant cost reduction in capital and maintenance dredging. As a riverine country, Bangladesh is crisscrossed by rivers and, according to Bangladesh Water Development Board BWDB), about "230 rivers flow during summer and winter"[1]. Many of these rivers flow deep and fast, carrying huge piles of sediments carving from their banks or from the mountains where they emerge. While

[1] *www.bwdb.gov.bd* , Bangladesh Water Development Board (BWDB), last updated on 2012-07-02

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flowing down towards the sea, these submarine sediments deposited disproportionately in places in the widening channels and beds, form deltas, encroach the depths of the rivers, block the mouths of the rivers, limit their capacity to flow water- a root cause of the flood and submerging agricultural lands- and destroy the navigability of the commercial transports and other natural uses of the rivers. Accordingly, dredging the parts of the rivers, estuaries, harbours and ports and maintaining a certain level of depth and navigability throughout the year become economic, geological and political essentiality for Bangladesh, to facilitate transportation of commercial vehicles, protecting agricultural lands, keeping fish farming and other bio- diversities undisturbed and minimising environmental hazards like preventing floods, etc. Indeed, Bangladesh Inland Water Transport Authority (BIWTA) and BWDB spends billions of dollars (USD) for maintenance and capital dredging across the country.

The integration of AI along with its associated branches like Big Data, Machine Learning, Internet of Things (IoT), Blockchain and application of Simulators, Actuators, and Sensors can significantly impact upon areas including the management, leadership, data processing, data management, dredging methods, increasing productivity, setting up equipment guidelines, recommended practices and identifying threats. In addition, it can also impact the efficiency and safety enhancement features of the dredging machines used in Bangladesh and help implement operational best practices among the stakeholders.

2. Objective of the Study

The study aims to enable the stakeholders to enhance dredging machinery and dredging systems by integrating AI and its associated branches into the existing systems and machinery. Here the associated branches refer to Machine Learning, Big Data, Blockchain, IoT and Simulators, and Sensors. The secondary objectives include mainly but are not limited to reducing the cost of dredging, harnessing the environmental impacts and implementing the operational best practices.

3. Scope of the Study

The scopes of the study are mainly but not limited to (i) how AI with its different branches can bring economic benefits and enhance efficiency in dredging machines, (ii) how using Big Data and Machine Learning can help the stakeholders to develop predictive models and applications to harness the challenges in capital and maintenance dredging especially, (iii) how using Big Data and IoT platform can ensure best operational practices and environmental safety, (iv) how AI and AI-based simulators have been integrated into the dredging machines and dredging jobs across the globe to enhance the efficacy of the machines and processes, and (iv) how AI Ready Approach and AI skilled workforce can potentially transform the capabilities of the organisation, management, dredging operations, the leadership of the stakeholders including those working in the government agencies like BIWTA, BWDB, Department of Shipping (DoS) and Bangladesh Ministry of Shipping (MoS).

4. Problem Statement

Tough AI can be a potential enabler to achieve the short term, middle term and long-term visions of Bangladesh Delta Plan 2100, especially in areas such as capital and maintenance dredging, the policy makers and industry leaders in Bangladesh are yet to understand fully how AI and its branches can be adopted into dredging systems. Besides, there are absence of infrastructure to support AI-based ecology, lack of skilled workforce and lack of funds. The research tries to address these challenges not only by trying to identify the areas in which AI and its associated branches can be incorporated into the existing dredging systems and machineries in Bangladesh but also by trying to highlight the benefits of such technological integration. Explaining how the systems and machineries becomes more efficient, environment friendly, safe, durable and time saving is one thing and bringing in a change in the cognitive process of the policy makers are two different things. AI-integration will most likely result in developing a reliable and integrated monitoring mechanism to locate areas that need to be dredged immediately, harnessing environment hazards and protecting bio-diversity, fish firming and agricultural lands. But whether these benefits will encourage the policy makers, leaders and top brasses to opt for changes remains uncertain. As minimizing the exorbitant cost of the different dredging projects running across the country remains a big challenge, the study tries to show how adopting to AI enabled technologies can reduce the cost of these projects. The study maintains

that, in addition to other benefits, the volume of money that could be saved by AI enabled machineries in dredging jobs can really encourage the stakeholders to adopt to AI enabled machineries and systems in Bangladesh.

5. Significance of the Study

Today's dredging is highly automated and industrial in scale. With the adaptation of AI in the machines, the operators can scoop, drag and vacuum up underwater sediments more efficiently, reducing the cost significantly. Again, the trucks, barge, pipelines, and conveyor belts used to dispose of the dredged materials can be integrated within the system, covering every aspect of dredging jobs holistically. Application of AI into the capital and maintenance dredging systems of Bangladesh can transform the dredging jobs into economic activity, creating scopes for the "spoil" [2] to be treated as economically scalable useful materials for landfilling, managing the coastal environment, ecological restoration, in manufacturing, and construction. Using Big data, the organisation can create predictive models to locate suitable areas for dredging, whereas the use of machine learning enables the stakeholders to develop simulations to upskill the dredging operators. All these activities would contribute to reducing the cost of dredging practically. Besides, connecting all the dredging machines used in different dredging sites with the help of IoT creates scope for effective monitoring and ensuring the best operational management practices and enabling the stakeholders to reduce carbon emission harnessing other barriers impacting the environment harmfully.

6. Methodology

The researcher qualitatively collected the primary data from the observations of the participants in the surveys, interviews and focus group discussions. The online survey carried out among the stakeholders included quantitative closed-end questions to evaluate different aspects of the scopes of the study. The study population includes dredging professionals (85%) with work experiences ranging from 4 years to 30 years and students (15%) as well and designation wise they are serving in posts such as addition chief engineer(7.7%), advisor consultant(7.7%), assistant naval architect(7.7%), chief executive officer (7.7%), director (technical)(7.7%), engineer and ship surveyor and examiner (7.7%), general manager (7.7%), manager (7.7%), mariner surveyor (7.7%) and senior marine surveyor (7.7%) in institutes and organisations like BUET, Banga Dredger Ltd, BIWTA, BWDB, DoS, Bashundhara Dredging Company Ltd, Bashundhara Infrastructure Development Ltd, Bureau Veritas Marine & Offshore, Karnafully Ship Builders Ltd. and Lloyd's Register Bangladesh Pvt. Ltd. The fundamentals in benchmarking the process of evaluation of the applications of AI into the systems include 1- "Understanding AI Ready Approach", 2-"Strategies for Implementing AI", 3-"Data Management", 4-"Creating AI Literate Workforce and Upskilling", and 5-"Identifying Threats".

In this study, the "Regulatory Body" mainly refers to but is not limited to regulatory bodies' organisational structure, management, and leadership. "Stakeholders" refers to different government organisations and other private organisations that are linked to dredging jobs. Finally, "Workforces" refers to all the officials ranked differently in the hierarchy of these organisations, especially the employees who directly handle maintenance and capital dredging jobs in Bangladesh.

The instruments of the qualitative and quantitative studies have been designed to address areas including social, political and economic and technological aspects and barriers in the process of implementing AI integrated dredging systems. Books, journals, reviews, research reports, websites, newspapers, magazines and government records, used as the sources of secondary data, have been multidisciplinary, covering AI, dredging engineering, environmental impact, economic science and management and government policies.

7. Dredging in the Context of Bangladesh – A General Overview and Literature Review

Dredging, referring to the excavation of subaqueous or underwater soils and rocks [3], includes four phases, namely (i) excavation, (ii) transportation of sediment vertically, (iii) transportation of sediment horizontally and (iv) placement of the dredged material. As a riverine country, Bangladesh requires to run massive dredging projects all over the year across the county, mainly to increase Increasing the depth of navigational rivers, building and reclaiming industrial or residential areas, restoring of habitats,

replenishment of beaches, mining and flood control etc. [3], and like what we see in other countries, the typical dredging jobs in Bangladesh fall into three categories namely capital dredging, maintenance dredging & clean up dredging [4].

The way it is carried out in different project sites across the country, capital dredging is mainly done for the creation or extension of river basins, harbours, marinas, canals, and other facilities. In contrast, maintenance dredging keeps the navigability of the rivers, waterways, channels, and harbours undisturbed. Moreover, the clean-up dredging is done to remove polluted material to safeguard human health and environmental protection [5].

Like the dredging method followed in other Asian countries, stakeholders follow hydraulic or mechanical methods of dredging, depending on the hardness and amount to be dredged, the disposal method, the location exposer, and the project outcome required, as well as sea conditions, water draft, channel width, transport distance, plant mobilization, limited working space, debris, and so on [3]. Hydraulic dredging uses water flow for erosive working, whereas mechanical dredging applies knives, teeth, or cutting edges. Mechanical dredge includes Grab dredger, Dipper, Bucket ladder dredge, and Backhoe dredge [6]. Dredgers commonly employed in capital dredging are Cutter suction dredgers, Backhoe dredgers, Bucket ladder dredgers.

The cycle of dredging process involves three steps, namely displacing sediment in a riverbed, transporting dredge material from the river bottom to the surface, and discharging the sediment to a discharge site [7] using pipelines, barges, in hopper dredgers, currents and waves. It has been discovered that over 90 percent of sediments from maintenance or capital dredging are unpolluted and intact, and this can be used as a resource [7].

The regular dredging jobs in different rivers and estuaries under BIWTA and BWDB is yet to explore the full potential of AI, as the record of previous dredging history limits its application only in sharing the already stored geological, cartographical and geo-satellite data among the engineers from different departments. The river depth surveyors collected the data manually, who relied mainly on depth finders or echo sounder to locate areas where the rivers might require dredging to ensure navigability and protect the agricultural land from being flooded.

The practice of taking the aerial views of the landscape and rivers by the drones and Bangabandhu satellite to track and predict river flows has been a recent development. In general, the data collected for the studies referred to the understanding of the soils and subsoils at the dredging sites and the understanding of marine surroundings such as types of sediments, wind turbidity, water depth, currents, waves, temperature and salinity. The researchers and engineers shared this information maintaining a chain of the network, something that resembles the types of services facilitated by Blockchain and IoT and the ways they filtered and analysed this information taking help of the machines and computer-generated data was similar to how things are done using the augmented intelligence, though, in reality, no serious use of AI was in practice formally.

The much-hyped Padma Bridge, the country's largest bridge, is built on "42 concrete pillars"[2] that required significant well-dredging experience before their installation. These pillars were installed in the deep river beds were carrying out dredging jobs that required the machines to perform repetitive tasks. "It was the most challenging and crucial job of the bridge," Padma Bridge Assistant Engineer Ahsanullah Majumder Shaon confirms. The Chinese company assigned for the dredging, piling and river training jobs deployed heavy equipment like three large dredgers, three high-powered modern tugboats, one anchor boat, and a 500-tonne floating crane [3]. Figure 1 shows the dredging carried out for piling of the river Padma bridge and Figure 2 shows the typical cutter suction dredger used for such operation.

Engineers installed different sensors, devices and tools to collect data related to river current, depth, salinity, soil characteristics, and piling and used them in completing the other successive piles in different locations, thus using data processing technologies and augmented intelligence to complete the piling jobs within the stipulated time.

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[2] "Padma Bridge's 14th span to be installed Saturday" , https://www.daily-sun.com/post/402955/Padma-Bridge%E2%80%99s-14th-span-to-be-installed-Saturday, retrieved on 28th June, 2019 12:30:23 PM.

[3] https://www.observerbd.com/2014/10/24/50574.php, publication date: 2014-10-24, publish time: 19:42.

Figure 1. Dredging for piling in Padma rivers for Padma bridge [8]

From a global perspective, the application of AI has already started gaining momentum, as both the government and private agencies and companies worldwide are taking great interest in applying the technologies in the existing dredging jobs and machinery well. In 2008 during March and July at the artificial entrance to the Gippsland Lakes, Victoria, Australia, as a part of Geographic Information Systems (GIS) based monitoring, regular hydro-data were collected before, after and during the process dredging jobs. The study demonstrates how the use of spatial data in conjunction with GIS-based monitoring technology enables stakeholders to improve their understanding and consensus-building regarding maintenance dredging operations, morphometric evolution, and the relationship between natural processes operating throughout the catchment-coastal-marine continuum [9]. Collecting such vital information to support the stakeholders' consensus-building relating to future sediment management challenges was possible only because of GIS-based technologies.

Figure 2. Cutter suction dredger used in dredging for Padma Bridge [8]

Furthermore, the dredging project in the Province of Banten, Republic of Indonesia, can also be cited as a case study justifying the efficiency of applying AI in dredging jobs. The government approved dredging operations in the vicinity of PGN's offshore pipeline. To evaluate the dredging activities effect, the study included a 3D sediment transport and hydrodynamics simulation. It was aimed at measuring the effects, Describe the extent, if any, of the increased current and erosion along the pipeline induced by dredging activities [10]. The research finding concludes in recognising the three-dimensional hydrodynamics and sediment transport model as a reliable tool to determine the best pipeline route to minimise the risk, and most importantly, the modelling resulted in the computer, and the practical observations confirm where severe free span pipeline occurs in the erosion region.

AI-based tools for monitoring river current, salinity of the water, depth of the river beds from the surface layer of water, water quality, and oceanographic conditions are gaining popularity for their precision and reliable data sourcing. At Port Everglades, the US Army Corps of Engineers tests an artificial intelligence application for monitoring water quality and oceanographic conditions [11]. Massive dredging projects are always threatening to their ecological surrounding if the impacts are not studied ahead of time. Hence the army took up the monitoring effort, which became a necessity for adaptive management of the dredging projects. Figure 8 shows how project data can be utilized monitoring and ecological forecasting.

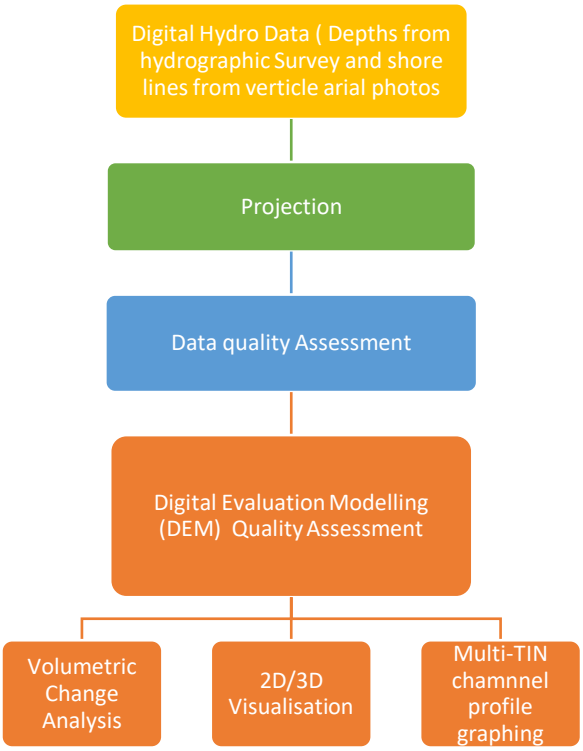

Figure 3. Project data flow chart of digital Hydro-Data [11]

The US Army Corps of Engineers (USACE), Jacksonville District, in collaboration with the National Oceanic and Atmospheric Administration (NOAA) and the US Army's Engineer Research and Development Center (ERDC), tested NOAA's ecological forecasting tool, dubbed "Environmental Information Synthesizer for Expert Systems" (EISES), for the first time in a maintenance dredging project as part of a cross-organizational collaborative effort to help capture the effects of climate change EISES accelerated and automated the analysis of environmental data from satellite photos, in-situ equipment, and in-situ observations, as well as gathered responses to ecological events, with the assistance of artificial intelligence. EISES' present collaboration intends to collect data from sensors mounted on the seafloor in order to determine turbidity, total suspended solids (TSS), sediment deposition, seabed light (PAR), waves, currents, temperature, and salinity [12].

8. Integration of AI into the Dredging Systems

In terms of upgrading dredging machinery, the application of AI creates enormous opportunities and possibilities. By definition, artificial intelligence is the practice of making computers intelligent, and intelligence is the trait that enables an object to behave appropriately and predictably in its environment [15]. In other words, it enables a computer or a person to think like a person. However, many people use AI to mean computers that use algorithms to process a large volume of data, draw conclusions, and learn from experiences. With AI comes the concept of augmented intelligence, which is essentially a human-centered partnership paradigm in which humans and AI collaborate to improve cognitive function [13] in areas of learning, decision making and problem-solving while facing new challenges.

Augmented intelligence interacts with people and improves what they already know, reducing the mistakes and therefore carrying the potential to improve the routine work and repetitive jobs of any machines, including those commonly used in maintenance and capital dredging jobs in Bangladesh. Moreover, augmented intelligence, if applied properly, can be more effective with automation as it complements the machines with AI and human touch. Figure 4 shows possible usage of AI in different branches of analysis and application.

Again, an adaptation of Machine Learning, which uses mathematical models to extract knowledge and patterns from data, can help organisations handle its exponential growth of data volumes and computing

infrastructure. For example, using data analytics and ML algorithms like Volvo[4],concerned dredging authorities can predict when parts of the dredging machineries might fail or when the machines need servicing, thus improving safety and minimising the cost of repairing. Simulators developed with the help of feeding data of a particular area can help the stakeholders identify the appropriate site location and appropriate machines for dredging and upskilling the operators and ensuring better monitoring and operation of the dredging jobs.

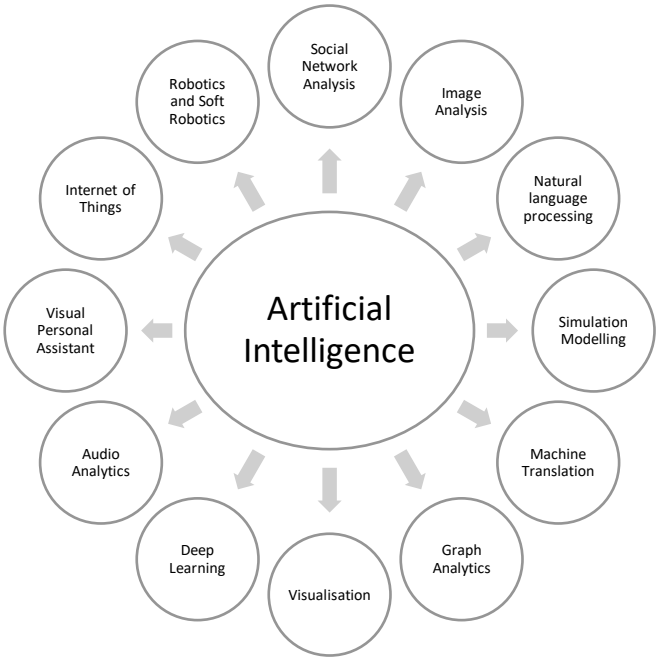

Figure 4. Different branches of AI [13]

Over the past two decades, there has been a revolution in harvesting the potentials of AI by different organisations around the globe, and with the advent of 5G with faster network connectivity, what is more impressive about the application of AI or Big Data or IoT is the fact that now the data can easily and safely be shared even in near real-time among the interested groups of researchers, departments and organisations for achieving the desired goals without repeatedly investing in the same project, whatsoever, provided the organisations should agree on giving access to their research data. For example, the data accumulated by Volvo's pilot project for detecting driving conditions have been shared with the Swedish highway authority, helping other organisations and individuals to know vehicles performance in hazardous situations, such as when the roads are icy. Similarly, data accumulated from one dredging project can be shared with the stakeholders in other projects. Using Big Data, the operators in other projects can cull out patterns that might significantly reduce the cost and efficacy of the dredging machines. This particular cross-organizational application of data demonstrates further that "Block Chain" is another ground-breaking AI technology that is cryptographically secure but fundamentally open, ingeniously powering a public ledger to which everyone has access but no single person controls, enabling businesses and individuals to collaborate with an unprecedented level of trust and transparency [14] is out there to change the future roadmap of technological applications in their real-life settings.

As the metamorphic agents, humans can now move the world faster, and Roger Hooke (1994) compares this motion with the pace of rivers, waves, wind or glaciers. With the use of AI, dredging issues that were earlier considered challenges can now be turned into an advantage. The dredging waste can be the case here in point. Earlier it was considered as "spoils" and waste materials and didn't have any significant use. Over the period, due to industrialisation and urbanisation, these spoils have emerged as highly useful materials for protecting coastal areas and environment, ecological restoration, use in manufacturing and construction [16].

[4] https://www.bernardmarr.com/default.asp?contentID=692, "Volvo: Machine learning-enabled analytics on a large scale", retrieved on 12/03/2021

8.1. Use of Simulators

The use of simulators for dredging by the government, semi-government, military units and private companies like Royal IHC around the globe can be traced in three major activities, namely, for upskilling of the dredge crews (operation), upgrading of already used machinery for dredging especially in hopper dredgers and cutting suction dredger and excavators (upgrading and automation) and in cost estimation of dredging projects (evaluation and estimation).

The use of simulators facilitates practical training and "helps the trainees learn the dredging trick" [17]. Interestingly, using data logging, a monitoring system, and Machine Learning technology, three-dimensional virtual dredging sites can be created, allowing the trainees to see the surface view from the control room or bridge and the underwater view when required. eXcavator Position Monitor (XPM), Dredge Profile Monitor (DPM) or Dredge Track Presentation System (DTPS) are some of the popular training simulators for dredging used for enhancing operational skills, positioning and learning and progress. Jan de Nul uses one-hopper simulator, and on cutter simulator, Deme uses one cutter simulator, and Zeebrugge uses one-hopper dredger simulator to train staff, dredging crews and new learners.

8.2. Developing Morphological Modeling by Using Machine Learning

Mathematical models enabling the consultants to design dredging conditions need to be accurate, and Machine Learning with its ability to analyse large volumes of data at a time can Identify intricate patterns that would have been missed by human analysis[5] and help predict river flow, navigability, and river flooding phenomena. "BWDB and Institute of Water Modeling (IWH) have already developed two dimensional and one-dimensional mathematical models of 8 rivers including Atrai, Ganges, Brahmaputra-Jamuna, Padma, Old Brahmaputra, Karnafuli, Meghna (Upper) and Lower Meghna" [18] signifying that the researchers are already equipped with necessary data that is required to give as input for the developing three-dimensional models using machine learning. Having a correct reading of river flow, navigability and flooding factors increases the chances of enhancing efficiency and service quality in capital and maintenance dredging. As machine learning is a kind of software library or toolkits that help execute the task, there are plenty of possible programming languages, though Python is considered to be the most popular programming language so far for machine learning. The stakeholders of dredging projects can also reduce the cost of dredging by using Python to develop accurate mathematical modelling tools.

8.3. Using Big Data in Strategic Planning for Dredging

Using Big Data in Multi-Criteria Decision Analysis (MCDA), policymakers can be more accurate in strategic planning to create a model for river dredging management that is optimal. Huge volumes of dredging related structured, unstructured, exhaustive, relational, flexible and scalable [19] data collected and stored by the different stakeholders in near real-time on types of dredging machinery, dredging processes or methods, the navigability of the rivers and waterways, bank erosion, scaling morphological process, location of dredging site, length of dredging job, alignment of river dredging and river training works for the main rivers and distributaries, cost of dredging, impacts of seismic events, and human interventions, disposing of dredging spoils, mitigation plan, enhancement plan, contingency plan, compensation plan, location of disposing of the dredging spoils, and social and environmental impacts can be used to create a comprehensive data lake, enabling the stakeholders to decide more efficiently about the weighing factors on dredging machines, dredging points, disposal sites and dewatering machines. According to Anchul Jeong [20] National Institute of Environmental Research, Seoul, South Korea, the "cost of dredging differ approximately by 18% due to weight factors".

8.4. Integration of AI System in Dredging Machinery

The type of machines used in the capital and maintenance dredging in Bangladesh includes Cutter Suction Dredgers (CSD), Backhoe Dredgers (BHD), Water Injection Dredges (WID), Grab Dredgers (GD), Stationary Suction Dredgers (SD) and Trailing Suction Hopper Dredgers (TSHD). Customising and

[5] https://algorithmia.com/blog/how-machine-learning-works, "How machine learning works" retrieved July 22, 2021.

upgrading these machines using AI, especially integrating them with AI systems with Programmable Logic Controllers (PLC's), can adjust dredging pump speed, mixture density, mixture velocity, and overground speed, keeping the measurement issue accurate, reducing system loss and enabling the dredgers to adjust to the optimal set point for a given situation.

Royal IHC, a leading manufacturer of Dredging Equipment worldwide, has programmed the dredging machines with the help of a combination of measurements, mathematical models and algorithms to control the dredging machines even if the underwater dredging circumstances such as soil structures and components, depths, speed and direction of the water flow etc. change. The integrated Dredging Control System (DCS) has boosted the efficiency of dredgers by monitoring and controlling critical dredge process equipment either manually, automatically, or through the application of artificial intelligence. A monitoring system is used to fix the suction tube's positions and angles and is commonly known as Suction Tube Position Monitor (STPM). How algorithms successfully develop the AI system in the dredgers has been well explained in Increasing dredging production while optimizing the personnel and minimizing fuel usage [26]. Monitoring and automation of cutter suction dredgers were impossible until recently. However, now with the help of AI, the parameters of grain size of pumped materials can be measured, enabling the machines to increase "productivity by 10-15%"[6].

Bangladesh, according to the Ministry of Shipping, requires dredging of at least 1,65.5 million cubic metres of river routes annually. Given the country's current dredging capacity of 84.6 million cubic metres, increasing production capacity by 10% to 15% by existing cutter suction dredgers will undoubtedly reduce the cost of maintaining the navigability of 100 major rivers [7], as approved by the Executive Committee of the National Economic Council (ECNEC) in October 2019. Additionally, by integrating AI systems in collaboration with competent manufacturing companies that are leaders in the field of automated dredging equipment, BIWTA under the Shipping Ministry will be able to increase dredger uptime and reduce fuel consumption and emissions, prevent water hammer, clogging pipelines, and cavitation, identify failing sensors ahead, and provide operators with greater peace of mind. Installing the ECO Pump Controller (EPC) on dredgers optimizes the dredge pump's capabilities and pipeline production. Additionally, it will eliminate water hammer, cavitation, and clogging of the discharge pipeline, which will serve up to three on-board dredge pumps and four booster pumps concurrently. Kalman and other algorithms are used to process and filter the data from available dredgers coherently. Thus, the effectiveness of AI applications is contingent upon the installation of accurate DPM, production, pump pressure, and torque data. As part of the Automatic Cutter Controller, the modules installed within the EPC can cooperatively work and act as the whole AI-based mixed transportation chain control. Sensor Diagnostics (SD) assist in identifying malfunctioning sensors by studying the signals. The bottom line is that the more AI apps implemented, the more efficient the system will become.

8.5. The Automated Cutter Controller

The "IHC Systems ACC" [8], operated by ACC registered algorithms and models, can increase the efficiency of cutter controller up to 30%, and if the same type of program is installed in the existing dredgers of Bangladesh Shipping Ministry to automate cutter controllers including cutter head, dredge head, cutting edge of a bucket and waterjets, the efficacy of dredgers will increase significantly, generating high economic and ecological benefits, achieving optimal utilisation rates, reducing dredging time, downtime and wear, and making the dredging process smoother and preventing under-over dredging. The IHC Systems ACC uses the popular hardware and software and programmable logic controller network (PLC) monitored by a PC-based, server-client, supervisory, control, and data acquisition (SCADA) network and uses ACC registered algorithm and models. Figure 5 shows the multipurpose cutter head developed using developed with computational fluid dynamics (CFD) analysis and specific teeth available for each type of soil.

[6] *https://www.royalihc.com/en/products/dredging/cutter-dredging/csd-artificial-intelligence*, retrieved: July 23, 2021.
[7] https://www.thedailystar.net/city/news/govt-procure-55-dredgers-1748413, retrieved: June 21, 2021.
[8] https://www.royalihc.com/-/media/royalihc/products/dredging/cutter-dredging/automatic-cutter-control/d1_brochure_acc.pdf

Figure 5. Multipurpose cutter head [21]

8.6. IoT and Mitigation of Environmental Barriers and Ensuring Operational Best Practices

Installing different censors for carbon emission, fuel consumption and engine efficiency in every dredger operating in the rivers, ports, estuaries, and other waterways and connecting each of them to a central Network System with the help of the IoT will help the organisation to learn and monitor carbon emission, fuel consumption and engine efficiency correctly and timely. Linking all the dredgers operating at different sites with the application of IoT, a timely enabler of machine maintenances, surveillances, and observations, Bangladesh Maritime Safety Administration, DoS can calibrate with IMO 2050 Decarbonization Charter and phase out the emission of greenhouse gases to a significant level from the dredgers and adapt to measures to thrive in the enforcement of the environmental safety regulations. IoT could be instrumental in ensuring on-board controls that can mitigate environmental impacts, according to the researchers. For instance, over dredging, excessive carbon and other GHG emissions, low engine efficiency, excessive consumption of fuel, noise pollution, air pollution, destruction of biodiversity, etc. Everything can be minimised by proper monitoring and timely detection. IoT can be a role changer in operational best practices by providing timely detection signals to the stakeholders when there is any deviation from the standard concerning environmental safety and project goals.

The experience of Jan Wassen, the director of business intelligence for Volvo, can be a case here in point. As a part of the project to make the car smart and safe, he first identifies areas where data analytics and ML algorithms can produce the maximum benefits. With careful observations, he finds that if connected and empowered by a smart data network, i.e. IoT; the systems can generate more and more data that are increasingly demonstrated by the cars. Hence, he decides to launch VOLVO's first car with internet connectivity, enabling the company to evolve its data strategy and initially enabling the systems to predict and identify well ahead of time the parts that may fail shortly or the vehicles that may require servicing shortly. As a result, today the Volvo uses data to uphold its impressive safety reputation.

9. Minimising the Cost of Dredging

According to the Royal IHC, Integration of AI enhances the productivity of dredgers from 10 % to 15% and increases the performances of the automated cutter controller by 30%, enabling the stakeholders significantly to minimise the cost of dredging over the period [22]. The money to be spent integrating AI with the existing dredgers is very insignificant compared to the amount upgraded, and automated smart dredgers are likely to save in the long run. BIWTA and BWDB need to carry out dredging jobs in Bangladesh, mainly in rivers, port and harbour construction and maintenance, land reclamation, coastal protection, offshore trenching, environmental dredging and lakes and reservoirs construction and maintenance. A close look at the budgets of the ongoing dredging projects of BIWTA and BWDB will help to draw a summary of the amount Bangladesh can save by upgrading the dredging machines with AI run applications and algorithms. Table 1, showing the estimated cost of the ongoing projects of BIWTA, could be an eye-opener for everyone.

Table 1. Cost of different ongoing dredging projects under BIWTA[9]

Sl.	Name of the project	Implementation period	Estimated Cost in GBP (Million)
1	Capital Dredging of 53 river routes in inland waterways (1st phase: 24 River Routes)	July 2012 – June 2021	168.80
2	Bangladesh Regional Waterway Transport Project-1 (Dredging in Chittagong-Dhaka Ashuganj IWT Corridor along with associated linked routes and construction of terminal with allied infrastructure)	July 2016 – June 2024	280.90
3	Improvement of navigability from Mongla to Pakshi river route via Chandpur-MawaGualanda	July 2017 – June 2025	83.93
4	Improvement and Restoration of Navigability for Old Brahmaputra, Dharala, Tulai & Punarbhba River	September 2018 – June 2024	383.80
5	Construction and placement of special type terminal pontoons with allied facilities	July 2018 – December 2020	14.3
6	Feasibility Study for River Management by enhancing the navigability. Minimising drainage congestion. Wetland ecosystem, irrigation and landing facilities by capital and maintenance dredging in Barisal division.	February 2019 – June 2020	0.37
7	Procurement and Installation of Navigational Aids for Inland and Coastal Waterways	July 2019 – December 2020	4.4
8	Establishment of Dhaka-Laksmipur Navigational route on Meghna (lower) River	January 2019 – June 2022	4.4
	Total = 940.9 million GBP		

It is evident that Bangladesh spends a huge currency every year on capital and maintenance dredging; in most cases, the stakeholders use cutter suction dredgers. If the stakeholders decide to upgrade the machines with the application of AI into its functioning mechanism, the productivity of these dredgers can increase between 10% to 15%. The existing ongoing projects of BIWTA will require 940 million GBP to complete, and a large chunk of this money, according to BIWTA's development official, is spent on machine operating costs ranging from 50 % to 70% of the total cost of the project. If the productivity of these machines increases by 15%, it means the country can save over 141 million GBP from these projects by investing in upgrading these machines with the help of leading manufacturers and engineers who are successfully working on the application of AI in the dredging equipment and machinery.

Taking into the total volume of dredging Bangladesh needs to do every year, its cost per cubic centimetre will also help to find out the money Bangladesh can save every year by upgrading and increasing the productivity of the machines. For example, it costs 0.6 to 0.87 GBP for dredging each cubic foot, meaning dredging per cubic meter ranges between 22 to 31 GBP. Therefore, Bangladesh needs to dredge 165.5 million cubic meters every year, though, with the existing set-up, it can dredge only 84.6 million cubic meters. The cost of dredging and the money Bangladesh can save are shown in Table 2 below:

Table 2. Estimated cost of annual dredging: Target vs Reality

Dredging Volume cubic meter (million)	Dredging Cost per Cubic Feet (GBP)		Dredging Cost Per Cubic Meter (GBP)		Total Cost of Dredging (Billion GBP)		Total saving from the cost , if the application of AI system enables the machines to increase the productivity by 15% (Million GBP)	
165.5	Low	0.6	Low	21.2	Low	3.5	Low	525
	Mid	0.75	Mid	26.5	Mid	4.3	Mid	645
	High	0.87	High	30.7	High	5.1	High	765
84.6	Low	0.6	Low	21.2	Low	1.8	Low	270
	Mid	0.75	Mid	26.5	Mid	2.2	Mid	330
	High	0.87	High	30.7	High	2.6	High	390

It is visible that Bangladesh could save ranging from 270 million to 765 million GBP, if the productivity of the dredgers increases by 15%.

10. Smart Utilization of the Spoils

Usually, the dredged materials or the spoils are transported through the conveyor belt, grab, or ship. In dislodging the sediments, 91% of dredged materials are disposed of by hydraulic pipelines, whereas the remaining 9% of dredged materials, according to the survey, are relocated by mechanical means. Only 7.6%

[9] http://biwta.portal.gov.bd/sites/default/files/files/biwta.portal.gov.bd/page/860b0ae5_6e04_4aa1_a4c0_90e09105e7f8/2021-11-08-07-33-4998a5cdb20359176dd664dd2fe2e28a.pdf and developed by author

of the spoils is sold to the contractors, and 1.3% is used for beach nourishment, and another 15.2% is used for land reclamation, whereas the other spoils are usually disposed of in a content site (15.2%) or underwater (10.1%) or a pit (19.15) or on land (26.65) on in wetland creation (5.1%) [23].

Apart from political and economic considerations, the discharge, relocation and use of the spoils can be done smartly to minimise the cost by bringing in smart changes in the ways through which these spoils are transported through the pipelines, by smartly regulating the mixture by valve wear-resistant materials for every soil type. Furthermore, upgrading the systems with an AI run application enables the stakeholders to customise and configure the spoils discharge system for all working conditions, making it more wear-resistant and increasing its efficiency. Royal IHC's TSHD Dredge Line Components can be cited as an example.

11. AI Ready Approach: Cognitive, Behavioral and Emotional Transformation

Raising awareness about AI's catalytic prospects in increasing the dredgers' efficiency and productivity remains a primary challenge, as only 7.7% of the respondents very strongly recognises the potential of AI. However, one hopeful aspect is that 46.2% of them are moderately aware and believe that AI can play a significant role in increasing the efficiency of the machinery, minimising the cost and harnessing the environmental impacts.

What seems more promising here is 46.2% of the respondents moderately agree and believe that the stakeholders are aware of the need to take up the daunting challenge of implementing AI in their organisation to handle the cognitive complexities and the threats in dredging fields. In support of these statistics, 23.1 % of respondents strongly agree that the stakeholders understand that assisted intelligence can help them make decisions faster and better, especially in processing statistical data, detecting the areas that require dredging in the immediate future. However, a big challenge lies in the process of making the stakeholders ready to facilitate AI, humans and machines to learn from each other as part of the augmented intelligence and find solutions that will be more secure, reliable, faster and effective, especially in ensuring high performance of dredgers, keeping data protected and facilitating the upskilling of the workforce. The bottom line is that the workforce is not ready to think differently, and the cognitive change may require some time.

The statistics on the behavioural transformation of the workforce to act differently validates the previous finding, as only 15.4% of the respondents moderately agree that the workforce, especially the engineers and other officials dealing with dredging jobs, is ready to adapt to constantly shifting power and prospect of AIs. However, 61.5% of respondents strongly agree that by upskilling the workforce with technical knowledge and skills, the authorities can collaboratively create AI-compatible systems across different teams within the organisations.

Again, as far as emotional transformation to react differently is concerned, 53.8% of respondents are completely neutral in deciding whether the workforce perceives the idea of learning to tolerate an environment of risk and ambiguity, though 23.1% think that the workforce has the resilience, courage and confidence to take the lead in driving the changes that AI is going to introduce.

11.1. Strategies for Implementation: Organization for Return of Investment

About strategies for implementation, especially for the return of investment, only 7.7% and 15.4% of respondents strongly and moderately agree that Bangladesh Public organisations have unity of purpose, determination and commitment to implement AI in their respective departments, making them transformative in the coming decades. Interestingly, 46.2% of the respondents moderately agree that the stakeholders are aware that the efforts to transform into a holistic AI framework will require the respective organisation to set policies that would ensure tangible returns of investment for each organisation and that will be tailored to the dredging needs, focusing on the rights and liabilities; labour and automation; bias and inclusion; and safety and critical infrastructure. Most significantly, as high as 61.5% of respondents strongly agree that organisations understand that having structured inception stating clear goals and clear responsibilities is essential to make AI strategy successful and that creating an agile, iterative and diverse cross-functional multidisciplinary team of professionals with IT and specialised in AI skills is a pre-requisite to find out how and where AI can be introduced.

11.2. Data Management - Teaching the Machines

The significant finding of the survey, according to 69.2% of respondents, reveals that the stakeholders strongly understand that teaching the machines to detect significant patterns and using AI in data and analytics can improvise the dredging jobs, dredging monitoring systems in addition to improvising the performances in management, security, logistics, transportation, training and raising situational awareness and data information processing. 92.3% of respondents strongly agree that integrating AI and analytics will help the stakeholders create better insight and manage risk better in dredging jobs and that the stakeholders to are aware of this. They are strongly hopeful that using a full AI ecosystem to aggregate data from different dredging sites in rivers, estuaries, ports, river channels of Bangladesh will help make the systems more effective and dynamic, enabling the stakeholders to take decisions faster better. According to 70% of the respondents, the stakeholders think that using the IoT will make them deliver faster and accurate output, without human to human or human to machine interactions. Using AI in data governing can help the dredging organisations be more reliable in their operation of dredging and dredging monitoring jobs. It will help maintain data life-cycle and enable them to get rid of unwanted data.

11.3. Creating AI literate Workforce and Upskilling Them

Creating awareness for AI literate workforce remains the primary challenge in executing the strategies for applying AI in the dredging machinery and the overall context of stakeholders. According to the survey, 38.5% of respondents strongly agree that the stakeholders are aware of it. Here, lack of funds in the national and organisational budgets for upskilling the workforce in AI, AI-based research, and technologies to implement AI. However, 46.2% of respondents strongly agree that upskilling at least 2% of the workforce to handle the dredging jobs in the organisation as data engineers and data scientists will help the organisation run the toughest jobs of creating, running and managing AI applications holistically in the organisation. Interestingly, the entire study population strongly agrees that partnership with research institutes and universities known for AI and sending staff to those places as apprentices will help upskill the staff dealing with dredging jobs.

12. Conclusion and Recommendation

AI based system depends on the integration of measurement, mathematical modelling and algorithms, central network linking many machineries deployed in different areas for dredging and in the monitoring cells and the data stored in the systems that include geo-satellite data, velocity, seismic data, , magnetic, , logs, surface and other surveys, seismic sections, charts, surface or subsurface maps and other geological and geophysical data.

The job of an AI-based system is not only about sensors that direct the machines to change their functionality and configurations automatically to be tuned up to adapt to maintain ideal performance to achieve optimal results with the changing circumstances in the dredging process like the speed of the river current, depth of the rivers, soil formation and nature, formation of the river beds and other environmental considerations, it also involves Machine Learning, Augmented Intelligence, Network (IoT) and Big data in an organisational setting to run the entire system holistically. With the aid of artificial intelligence algorithms, monitoring and automation options for increasing the efficiency of dredging equipment are conceivable, allowing the machinery to accurately detect grain size, improves loading/unloading efficiency by 10-15%, boosts uptime, decreases fuel consumption and emissions, eliminates water hammer, pipeline clogging, and cavitation, and reads the estimated value presentation for malfunctioning sensors [10].

Transform the existing dredging machinery and systems into AI compatible systems in the next fifteen years is strongly likely to save 70 to 100 million GBP in different ongoing projects of BIWTA over the period. According to the research findings, the inability to transform technologically may appear as a threat to the effectiveness of the systems in general. Failing to understand the complicated nature of how AI can work within the systems by the policy making body and the top brass in the hierarchy can result in big-budget

[10] https://www.royalihc.com/en/products/dredging/hopper-dredging/tshd-artificial-intelligence , "ARTIFICIAL INTELLIGENCE (TSHD)", retrieved on 15.04.2021.

for capital and maintenance dredging jobs. Identifying the areas of applications for AI into the dredging machinery and the systems and integrating them require immediate attention. Though there is an acute shortage of AI skilled professionals, it is high time that the stakeholders took necessary action and trained and upskilled the current workforce in AI literacy.

Indeed, AI as a breakthrough technology is a kind of an eye-opener. Integrating it into the dredgers of Bangladesh and enhancing their productivity enable the country to save huge chunks of money every year, ranging from 31.34 billion to 83.64 billion. The cost of upgrading the existing dredging machines, especially the cutter suction dredgers, is not exhaustive. Compared to the return of the investment, which amounts to as high as 83 billion, the amount to be spent for the AI integration is insignificant.

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References

[1] Tom Taulli, *Artificial intelligence basics: a non-technical introduction*, 1st ed. Berkeley, California, USA: Apress Publications, 2019, ISBN 9781484250273.

[2] Ashley Carse and Joshua A. Lewis, "Toward a political ecology of infrastructure standards: how to think about ships, waterways, sediment, and communities together", *Environment and Planning A: Economy and Space*, vol. 49, No. 1, pp. 9–18, September 2016, DOI: 10.1177/0308518x16663015.

[3] Nick Bray, *Dredging for Development*, 6th ed. Voorburg, Netherlands: International Association of Dredging Companies, The Hague, International Association of Dredging Companies (IADC) and International Association of Ports and Harbors (IAPH), 1997, ISBN:9789075254150.

[4] R. N. Bray, *Environmental Aspects of Dredging*, 1st ed. London, UK: CRC Press, 2008, Online ISBN: 9780203894897, DOI:10.1201/9780203894897.

[5] International Maritime Organization (IMO), "*Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 and 1996 Protocol*", London, UK: International Maritime Organization (IMO), 2003, ISBN-10: 9280141554, ISBN-13: 978-9280141559.

[6] Jhon B. Herbich, *Handbook of dredging engineering*, New York, USA: Mcgraw-Hill, 2000, ISBN: 9780071343060.

[7] International Association of Dredging Companies (IADC), *Dredging: the facts*, Voorburg, Netherlands: International Association of Dredging Companies, 2005, ISBN-10: 90-75254-11-3, Available: https://dredging.org/documents/ceda/downloads/publications-dredging_the_facts.pdf.

[8] Tanjil Hasan, "Padma Bridge piling work completed", *Dhaka Tribune*, July 15, 2019, Available: https://www.dhakatribune.com/bangladesh/nation/2019/07/15/padma-bridge-piling-work-completed, retried 15th August 2021.

[9] Peter J. Wheeler, James A. Peterson and Leen N. Gordon-Brown, "Channel Dredging Trials at Lakes Entrance, Australia: A GIS-Based Approach for Monitoring and Assessing Bathymetric Change", *Journal of Coastal Research*, vol. 26, no. 6, pp. 1085–1095, November 2010, DOI: 10.2112/jcoastres-d-09-00043.1.

[10] Muslim Muin, Entin Agustini Karjadi, Nita Yuanita and Izqi Yustina Ammylia Yusuf, "Application of a 3D Non-Orthogonal Ocean Circulation and Sediment Transport Model on Pipeline Risk Assessment due to Dredging Activity in West Java, Indonesia", *Journal of Coastal Research*, vol. 91, No. sp1, p. 1, Aug. 2019, DOI: 10.2112/si91-001.1.

[11] Maya Jordan, *"U.S. Army Corps of Engineers tests artificial-intelligence tool for monitoring water quality and oceanographic conditions at Port Everglades"*, January 2021, Available: https://www.army.mil/article/243575/u_s_army_corps_of_engineers_tests_artificial_intelligence_tool_for_monitoring_water_quality_and_oceanographic_conditions_at_port_everglades.

[12] Prableen Bajpai, *"Microsoft (MSFT) and Artificial Intelligence"*, August 2019, Available: https://www.nasdaq.com/articles/microsoft-msft-and-artificial-intelligence-2019-08-07.

[13] Laurence Goasduff, "*Smarter with Gartner*", September 2019, Available: https://www.gartner.com/smarterwithgartner/top-trends-on-the-gartner-hype-cycle-for-artificial-intelligence-2019.

[14] Don Tapscott and Alex Tapscott, *Blockchain revolution: how the technology behind bitcoin and other cryptocurrencies is changing the world*, New York, USA: Penguin Publishing Group, 2018, ISBN: 110198015X, 9781101980156.

[15] Ashley Carse, "Dredge", in *Lecture notes of Anthropocene Unseen: A Lexicon*, pp 121–125, February 2020, Published by Punctum books, DOI: 10.2307/j.ctv11hptbw.21.

[16] Riny Mourik and Jeroen Braadbaart, "Modern Dredge Simulators and Training-Means to Get a Dredge Crew More Efficient", in *Proceedings of the WODCON XVIII – 2007*, Orlando, Florida, USA, Published by CEDA, Available: https://westerndredging.org/index.php/woda-conference-presentations/category/57-session-3a-dredging-project-case-studies?download=222:2-mourik-modern-dredge-simulators-and-trainingmeans-to-get-a-dredge-crew-more-efficientpdf.

[17] Bangladesh Water Development Board, "*Feasibility Study of Capital dredging and Sustainable River Management in Bangladesh*", Published by BWDB, 2014.

[18] Danah Boyd and Kate Crawford, "Critical Questions for Big Data", in *Information, Communication & Society*, vol. 15, no. 5, pp. 662–679, June 2012, DOI: 10.1080/1369118x.2012.678878.

[19] Anchul Jeong, Seongwon Kim, Minseok Kim and Kwansue Jung, "Development of Optimization Model for River Dredging Management Using MCDA", in *Procedia Engineering*, vol. 154, pp 369–373, 2016, DOI: 10.1016/j.proeng.2016.07.494.

[20] J. Osnabrugge and P. M. Van den Bergh "Optimising Manpower and Reducing Fuel Consumption While Increasing Dredging Production", in *Proceedings of the WODCON XX: The Art of Dredging*, Brussels, Belgium, 2013, Published by CEDA, Available: https://www.dredging.org/resources/ceda-publications-online/conference-proceedings/abstract/447.

[21] IHC, "*Cutterhead with cutting edges at the forefront of the dredging challenge*", Published by Royal IHC ,Available: https://www.royalihc.com/-/media/royalihc/products/dredging/cutter-dredging/cutter-equipment/d1-ps-cutterheads.pdf.

[22] IHC, "*Artificial Intelligence CSD*", Published by Royal IHC, Available: https://www.royalihc.com/en/products/dredging/cutter-dredging/csd-artificial-intelligence.

[23] Bashir Obaid, *"Sustainable River management in Bangladesh through Capital Dredging: Mitigation of Environmental Impacts through Project Management & Operational Best Practices"*, MSc Thesis, Plymouth University, UK, 2020, Available: https://www.researchgate.net/publication/351362680_Sustainable_River_management_in_Bangladesh_through_Capital_Dredging_Mitigation_of_Environmental_Impacts_through_Project_Management_Operational_Best_Practices.