Sustainable River Management in Bangladesh through Capital Dredging: Mitigation of Environmental Impacts through Project Management & Operational Best Practices

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Abstract

Well-structured project management, careful and timely monitoring and operational best practices in the dredging projects in different rivers facilitate the local public authorities to mitigate the environmental impacts in Bangladesh. Determining correctly the key factors that affect the environment helps design pragmatic and operational roadmaps for maintenance and capital dredging projects. Additionally, the study must consider the difficulties inherent in dredging jobs, the techno-economic megaplan incorporated into Bangladesh Delta Plan 2100, existing river management practices, government policies and regulations, prior to attempting to reflect on what is most needed among stakeholders for the successful implementation of improvement measures. The study maintains that adequate environment concerns should not be integrated later while reflecting upon management, monitoring and operation, but during the project design stage of capital dredging.

At first, the study focuses on evaluating the present extent of awareness and practices of environmental mitigation measures regarding the handling of the dredged materials, operational energy efficiencies, stakeholders influence or perception on the implementation of environmental mitigation measures and barriers of application of best practices. Then it tries to determine strategies for developing a sustainable operational framework to mitigate these identified barriers. Finally, it proposes a framework for the mitigation of environmental challenges resulting from dredging jobs.

Besides, this study identifies some potential government policy gap which needs to be shrunk tightly for effective implementation of mitigation measures for sustainable dredging.

Keywords: dredging, capital dredging, maintenance dredging, stakeholders, Bangladesh Delta plan 2100, river management, sustainability, climate change, challenges, government policy gaps, framework.

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1. Introduction:

Sustainable water management is integral for Bangladesh to implement the visionary 'strategic tool' (Deen, 2017) to 'transforming Bangladesh to achieve its Sustainable Development Goals (SDGs) and a developed country by 2041(GOB 2018). Bangladesh has almost 405 big and small rivers, which drain 1350 billion m3 of water from the Himalayas to the Bay of Bengal with a total catchment area of 1.72 million km2 (GOB, 2018) during the rainy season. There are 57 transboundary rivers, of which 54 enter from India and the rest three from Myanmar(Jahangir 2013). Navigability of rivers plays a significant part in meeting up these visions(BIWTA 2019). Riverbed siltation or aggradation is a common phenomenon in Bangladesh rivers due to the carriage of huge sediment with low riverbed descent. Due to the arrival of uncontrolled silt load from external sources, its deposition over the riverbed and consequent reduction in the conveyance area of the rivers are always unpredictable. Channel bed aggradations are causing a rapid decline of the river regime. The environmental challenges faced by the country, according to United Nations, are 'monumental' (Deen 2017), starting from recurrent cyclones, perennial floods, widespread riverbank erosion to a potential sea-level rise, which might put about 27 million people at risk over the next two decades (Deen 2017).

Considering the long-term adverse impact of climate change for water sectors Bangladesh Government has already approved a long-term comprehensive roadmap as 'Bangladesh Delta Plan 2100' which integrates techno-economic holistic plans to be implemented throughout the country to secure the future of water resources and mitigate the likely effects of climate change and natural disasters (Embassy of Bangladesh to the Netherlands 2020). The project scopes must be aligned with the Bangladesh Delta Plan 2100 objectives. Again, monitoring or effective governance is critical to the success or failure of strategic initiatives, portfolios, programs, and projects (Project Management Institute, 2016).

By carefully laying out the principles of dredging projects, which have been routine work for Bangladesh, time, money, and the environment can be saved. Defining and approving the project's strategy, goals, and objectives; developing and establishing policies; establishing and supporting the portfolio, program, and project governance framework; ensuring interest-group participation; setting priorities; recognising strategic alignment; resolving risks; updating changes; determining the responsibilities of decision-making bodies and endorsing charters of governing bodies (Project Management Institute, 2016). Following that, operational management and its best practices are discussed, to balance 'costs and revenue to optimise net operating profit' (Hyes 2021) is 'the collection of actions that result in the creation of value in the form of commodities and services through the transformation of inputs into outputs (Heizer, Jay; Render, Barry et al,2016). Operational aspects of maintenance and capital dredging projects play a critical role in guaranteeing their effective completion, which will

undoubtedly result in unfavourable and intolerable economic and environmental implications for local public authorities and the general public.

2. Problem Statement

How far best practices and operational measures are implemented in ongoing dredging projects in Bangladesh contributes to the mitigation of environmental impacts, and identifying ways to improve the implementation of best practices while also attempting to mitigate barriers entails significant breakthroughs for each dredging project, ensuring its success in achieving its objectives. Here best practice and operational measures refer to dredging project 'strategy, goals, objectives, policies, procedures, portfolio, programs, project governance, stakeholder relationships (Project Management Institute, 2016), selection of dredging machinery and other necessary components for each project, identifying risks of each dredging project, ability to authorise the request, changes, funding, and budget of the dredging projects, available resources, project approval or termination, deliberation of duties, roles and responsibilities of the assigned personnel, decision-making abilities of the dredging project authorities, charter of responsibilities of the dredging crews, dredging plans, monitoring measures and KPIs, monitoring or evaluation roadmap, audit, incorporating the changes, project results and their evaluation and adhering to project goals and methodologies (Project Management Institute, 2016). Failure to address these challenges will almost certainly result in undesirable realities for dredging projects, ranging from needless high costs, extended project duration, major environmental effects, loss of agricultural land and navigability of waterways.

3. Added value of this study

Owing to Government's determination to implement Bangladesh Delta Plan 2100 steadily and systematically, the amount of dredging jobs is expected to grow at an exponential rate in the successive years, and it is in line with the country's SDGs according to the feasibility study of capital dredging carried out by BWDB (BWDB, 2014). There will be a substantial ecological impact if this is not being carried out in a sustainable way. Therefore, the study's findings as they are focused on barriers to implementation of the best practices for sustainable dredging in Bangladesh, deem to make the local authorities aware of the challenges while designing maintenance and capital dredging projects at any stage. Nonetheless, it attempts to advance a systematic framework for ensuring the sustainability of dredging jobs and maintains that, if properly implemented by competent local authorities, the research recommendations will contribute significantly to the development of dredging policies, the enforcement of effective control, monitoring, and materialisation of dredging projects, and the upskilling of dredging crews to be at par with the international standard ISO 140001,

ISO 50001, adapt the management system that is supportive and protective of environmental and cultural issues and necessitate the dredging stakeholders to provide construction, awareness, special education, training and policy support.

Further to that, the large volumes of dredged sediments & consumption of fossil fuels for the capital dredging jobs demand responsible handling of the operation in an environmentally sustainable manner.

4. Earlier Studies

A good number of international researches have been carried out to understand and evaluate the effects of dredging, mitigation measures, monitoring, barriers of implementation and (Bray 2008) policy formulation. Dredging and dredging related issues are well presented by (Bray, Bates et al. 1997, Herbich 2000, Randall 2004, Bray 2008) Besides, the Central Dredging Association (CEDA), Western Dredging Association (WEDA) and Environmental Committee of PIANC are the three additional sources of references from where adequate guidelines, standards and recommendations on dredging information can be extracted. Issues such as the ' use and production optimisation of the dredging equipment, the cost estimating and survey aspects such as positioning, depth control and tolerances' (ir. van der Schrieck, Gerard.L.M. ,2002) etc. plays a vital role in each dredging job.

Environmentally friendly dredging tries to optimise the precision with which operations are done to reduce the handling amount of contaminated dredge material. For this purpose, individual eco-friendly dredgers have been developed, primarily modifications of CSDs, Backhoe dredgers and grab dredgers (IADC 2011). It is now common practice to install in overflow line a "Green Valve" to minimise turbidity. Other adaptations are the disc bottom Cutter or Environmental Auger Dredger (IADC, 2009). The right dredgers reduce environmental impact. CSDs are most preferable in terms of environmental acceptability(Bray 2008, IADC 2014).

However, the summary of the earlier studies is indicative of the fact that efficient project operations and harnessing the environmental impacts rely largely on how correctly the dredging equipment, project design, and processes have been followed.

5. Methodology:

Both qualitative & quantitative research methods are being used in this study. Secondary and primary data being used in the 'process of naturalistic inquiry that seeks in-depth understanding of social phenomena within their natural settings and seeks to justify underlying reasons, opinions, and motivations'(Drury et al, 2011) to discover, recognise and clarifying circumstances, perceptions, approaches of ecological impacts & mitigation measures of dredging, and on the other hand, the quantitative research,

which has been 'specific, well structured, have been tested for their validity and reliability and can be explicitly defined and recognised' (Kumar 1999), was based on primary data only and was utilised through cross-sectional study design using an attitudinal scale to determine the spread of attitudes on dredging issues and barriers.

Secondary data, 'collected by someone other than the user' (Yates, Clarke et al. 2019), were compiled after literature reviews. Primary data, 'collected by the researcher himself', (Drury, Homewood et al. 2011)were structured & semi-structured in the forms of open and closed-ended questionnaires, interviews, and pilot surveys. The questionnaire was completed online and through face-to-face interviews. Then the responses are coded, i.e. 'the process of identifying interesting and silent features of the text within a text that relates to the research question or objectives' (St. John, Keane et al. 2014) was done manually.

6. Analytical Study of the Dredging Jobs against the Backdrop of Environmental Impacts Operational Best Practices and Police Regulations

Dredging, defined as 'the excavation of soils and rock from the subaqueous or underwater'(IADC and IAPH 2010) and comprised of four phases, including excavation, transportation of sediment vertically, transport of sediment horizontally, and placement of the dredged material to increase 'sufficient depth of navigational waterways, construction and reclamation of residential or industrial areas, restoring habitats, beach replenishment, flood control, mining, etc (IADC and IAPH 2010) fall into three categories namely 'capital dredging, maintenance dredging & clean up dredging (Bray 2008, CEDA 2015)

Capital dredging is used to create or extend basins, harbours, marinas, canals, and other facilities. Existing waterways, channels, and harbours are maintained by maintenance dredging. Clean up dredging is associated with 'the removal of polluted material to safeguard human health and environmental protection (IMO 2006, IADC and IAPH 2010).

Dredging methods and plants can be hydraulic or mechanical and according to researchers (6349-5:1991 1991, IADC and IAPH 2010), and depend on 'quantity and hardness of material to be dredged, disposal method, site exposer, project outcome required, sea condition, water draft, channel width, transport distance, mobilisation of plant, restricted working space, debris, etc (IADC and IAPH 2010). Hydraulic digging uses water flow for erosive working.

Mechanical digging applied to cohesive soils employs knives, teeth, or cutting edges. Dredge material transport through the conveyor belt, grab, or ship. Mechanical dredge is 'Grab dredge, Bucket ladder dredge, Dipper, and Backhoe dredge'(Herbich 2000). Dredgers commonly employed in capital dredging are Cutter suction dredgers, Backhoe dredgers, Bucket ladder dredger (Bray 2008).

Dredging Process involves, three steps, namely 'displacing soil at a riverbed, transferring the dredge material from the bottom to surface, and carrying the material to a dumping site'(IADC 2005) using (a) pipelines (b) barges (c) in self-contained hoppers of the dredgers and (d) using waves and currents.

With regard to sustainable relocation & treatment, contaminated dredged material require treatment which ranges from separation from clean sand to incineration. It is found that almost '90% of sediments which are from the navigation or capital dredging consist of unpolluted and intact sediment, and this can be used as a resource'(IADC 2005). Sustainable relocation or usage of dredged material are coastal protection, beach nourishment, farming, gardening, forestation, habitation growth or improvement, production of construction material, e.g. bricks and construction works, foundation fill, dikes (IADC 2005).

6.1 Environmental Management Practices Related to Equipment:

Contemporary dredgers are fitted with, or old dredgers can be modified by incorporating systems to minimise the environmental effects of the dredging process. Onboard controls can mitigate environmental impacts. For instance, over dredging can be minimised by proper monitoring and improving accuracy, which in turn reduces the total volume of material to be dredged, thus decreasing pollution & GHG emission.

6.2 Stakeholders and their Involvement

Stakeholders are involved in mitigating the challenges and raising awareness, exploring solutions, application of the solution and finally the managing the project. 'Identifying stakeholders and engaging them during the planning and decision-making process of the project contribute to mitigate issues and run the project in a smooth and timely fashion' (IADC 2020).

6.3 Environmental Impact

Unregulated dredging activities and disposal of dredged materials impact the environment, disturbing the ecology in general by contaminating water, land, air, sound and others. The impact is multidimensional with long term and short term and direct and indirect impact on habitats. Major pollutions which are involved with dredging are water pollutions (resuspension of sediments, blasting effect, resurfacing harmful organisms or transporting unwanted organisms etc), Sewage, garbage and oil discharge (BWDB 2014), reduction in nutrients, dissolved oxygen, Land related issues (Placement of dredged material, dust, the noise of reclamation plant, runoff of saline and freshwater to local watercourses, Air pollution ie GHG emission, NOx & SOx

emission(Castro, Ooijens et al. 2018), Noise Pollution (Noise generation from vessels and dredgers) others such as changes to riverbed configuration, changes in current, swells or drainage, and hence deposition, erosion or land loss, damage to archaeological assets, e.g. shipwrecks (IADC 2005).

6.4 Mitigation Measures for Dredging Projects

According to researchers, (Netzband and Adnitt 2009), there are six broad stages namely contracts, design and planning stage, equipment selection operation, institutional affairs, operational and control or monitoring and feedback , where these mitigation measures can be applied to a project to minimise impacts on the social, environment & financial sectors.

7. Operational Best Practices

The following subheadings (7.1, 7.2,7.3,7.4, & 7.5) show the summary of the literature reviews on the operational best practices for reducing environmental impacts. Sources : (WEDA 2000, WEDA 2004, Netzband and Adnitt 2009, IMO and WMU 2013, WEDA 2014, CEDA 2015, Dewan, Yaakob et al. 2018)

7.1 Contractual and project management mitigation measures:

Best operational practices include (i) setting up the environmental performance standards /goals and how they will be met, (ii) completing Environmental impact assessment (EIA),

(iii) preparing project/site-specific environmental monitoring program, and (iv) adopting the "Adaptive Management" approach.

7.2 Project Design and Planning

Best operational practices include (i) reducing the dredge area as far as possible, (ii) avoidance of over dredging, which reduces the frequency of maintenance dredging, (iii) placement is very critical when dealing with contaminated sediment. Using capping for contaminated sediments and (iv) protect Habitation and species, i.e., to adopt precise measures for protecting local habitat or marine species by shielding, relocation, compensation, etc.

7.3 Equipment-related Mitigation Measures

Best operational practices include (i) selection of environmentally friendly dredge equipment (Netzband and Adnitt, 2009), (ii) engaging the dredgers with appropriate capacity (iii) running efficient dredging operation, thus reducing GHG emissions, (iv) fixing pipeline leakages and using double skin or welded pipes, (v) minimising sound generation (vi) using silt screen and curtains and adopting low discharge velocity to minimise turbidity etc., (vii) maintaining the standard appropriate to the project and keeping the emission under control, viii) applying proper kind of dredged material transportation technique, (ix) optimising the environmental performance of equipment, (x) de-rating by improving the engine performance and attaining the max cylinder pressure (xi) using fuel oil additives to improve fuel combustion by the engines and (xii) monitoring main propulsion performance system.

7.4 Dredging operation related mitigation measures

The best operational practices include (i) minimising the vessel traffic (barge transportation) to reduce resuspension from propeller wash and ship-generated waves, (ii) bed-levelling or 'ploughing' in combination with other dredgers to reduce over-dredging, (iii) avoiding the overflow from transport barges and hopper to reduce the loss of sediment, (iv) minimising the underwater disturbance by selecting appropriate anchoring and mooring systems and adapting to appropriate anchoring method to reduce regular repositioning of anchors or spuds, which may cause bed disturbance, (v) keeping the water mammals and /or river dolphins at a safe distance from critical operations, (vi) avoiding the spill of oil/waste/chemical into water following a standard procedure like oil spill emergency plan and waste management plan and disposing of the engine room bilges to shore reception, (vii) shielding undirected lighting to reduce light irritations to migratory birds, fish or public, (viii) arranging healthy sanitary system and disposal of garbage such as sewage and plastic or other garbage to a shore facility, (ix) shielding of sensitive areas also reduces environmental impact and placing a physical barrier, i.e, silt screen, sheet pile walls, bubble curtains, oil boom to prevent the spread of suspended sediments, floating elements to a sensitive area nearby, (x) ensuring beneficial use of the dredged materials depending on their physical & chemical characteristics and creating and development of land, beach nourishment, capping, aquaculture, raw construction material, restoration of wetland, etc. and (xi) sending the dredged materials in treatment plants if the dredge materials fail to meet safety requirements (IMO 2006).

7.5 Control/Monitoring related Mitigation Measures

The operational best practices include (i) maintaining accurate horizontal and vertical positioning control of dredging by using advanced technology like DGPS and Data

logger, (ii) maintaining dredging information system to continuously monitor dredging variables such as depth, volume, position, etc, (iii) analysing the data to receive feedback system for dredge operator usage,(iv) keeping an updated 'Black Box' systems to confirm that required standards and specifications have been followed during dredging job, (v) monitoring fuel consumption and management,(vi) analysing the project performance and (vii) auditing regularly.

8. Policy and Regulatory Review

Dredging activities and stakeholders must comply with relevant national, local and international legislation and planning requirements. Policy, strategy, and regulatory issues are critical at various stages of project execution. External financiers like the World Bank have their own environmental policies (BWDB, 2015a).

8.1 Dredging related national legislations

Most relevant national legislation concerning environment & dredging are. Bangladesh Environmental Conservation Act, 1995 and amended in 2010 . Under this act, the River Management Improvement Program (RMIP) require clearance by the Department of Environment (DoE) before launching the project complying with procedures stipulated in the ECR-1997(Environment Conservation Rules). DoE defines ecologically critical areas under this act, which need to be considered while planning and designing the RMIP interventions. The followings are the different laws that need to be taken into consideration while carrying out dredging jobs in the context of Bangladesh.(BWDB 2015, (BIWTA) 2016)

8.1. Bangladesh Environment Conservation Rules (ECR), 1997

8.1.1. Water Act 2013

8.1.2.Bangladesh Environment Court Act, 2010

8.1.3. Protection and Conservation of Fish Act (1950)

8.1.4. Embankment and Drainage Act, 1952

8.1.5.The EIA Guidelines for Industry (1997)

8.1.6.Inland Shipping Ordinance 1976 and Amendment

8.2. Related State Policies, Strategies and Plans

8.2.1.Bangladesh National Environmental Policy 1992

8.2.2. Inland Water Transport Policy (IWTP) 2009

8.2.3. Bangladesh National Environmental action plan (NEMAP 1995)

8.2.4. 'National Water Policy (1999)

8.2.5. National Water Management Plan, 2001 (Approved in 2004)

8.2.6. National Fisheries Policy, 1996

8.3. Relevant International Conventions, Treaties, and Protocols (ICTPs)

8.3.1. International Convention for the Prevention of Pollution from Ships (MARPOL) 1973/1978

8.3.2. 'Biological Diversity, Rio de Janeiro (1992)

8.3.3. United Nations Framework Convention on Climate Change, Rio de Janeiro (1992)

8.3.4. Convention on Wetlands of International Importance, especially Waterfowl Habitat, Ramsar (1971) and its amending protocol, Paris (1982)

8.3.5. Convention (BONN Convention) on Conservation of Migratory Species of Wild Animals (1979)

8.3.6. 'Kyoto Protocol (1997) and the Copenhagen Accord (2009) on climate change

8.3.7. Convention on the prevention of marine pollution by dumping of wastes and other matters,1972

8.2 The implication of GOB Acts, rules & policies

Based on earlier discussion on environmental acts, every industrial unit or project based on their site and impact on the environment need to obtain an environment clearance certificate and will fall any of the four groups. They are category I (green), category II (Orange-A), Category III (Orange B) and Category IV (Red). All flood control related matters fall under Red Category. Therefore RMIP/capital dredging falls in the 'Red' category require EIA for environmental clearance (DOE 2010). The responsibility lies with the project owner to conduct an EIA, and DoE is responsible for reviewing the EIAs and issuance of the Environmental Clearance Certificate.

8.3 Summary of Barriers for a sustainable dredging operation

8.3.1 Awareness Barriers

They include mainly but are not limited to only (i) lack of awareness regarding mitigation measures among stakeholders, (ii) insufficient crew awareness, (iii) lack of competent crew and (iv) no binding formal training requirement for dredge crew.

8.3.2 Legislation /Policy Related/Institutional Barriers

They include mainly but are not limited to only (i) lack of dedicated national policy & legislation on dredging, (ii) inactiveness of regulatory bodies for implementation and monitoring, and (iii) binding-free behaviors from project owner/ contractors.

8.3.3 Technological Barriers

They include mainly but are not limited to only (i) equipment installation cost/difficulties, (ii) equipment maintenance cost, (iii) lack of credibility and immaturity of in assessment and in the technological application, and (iv) operational difficulties, i.e., safety and technical risk.

8.3.4 Financial Barriers

They include mainly (i) budget & cost-benefit issue and (ii) capital investment.

8.3.5 Organisational Culture Barriers

They include mainly but not limited to only (i) lack of interest in contractors/Owner, (ii) Intra-organizational difficulties in the company, (iii) Inter-organizational silo-centric difficulty, and (iv) lack of dedicated personnel & dept for dealing with environmental issues

8.3.6 Effective Monitoring & Management

They include mainly but not limited to only (i) lack of compliance & monitoring effort, (ii) lack of latest monitoring technologies, and (iii) lack of effective project management.

9. Discussion and Findings

A literature review or the secondary data provided insights into various theoretical aspects of this study, but little was revealed regarding existing practices and barriers in the context of Bangladesh due to the lack of earlier studies on this issue. Hence interviews were conducted to obtain the information with respect to the research. The literature review further reveals that there are insufficient Government act and policies to regulate and monitor ecological dredging impacts, and it may be due to lack of awareness, experience, expertise, and resources, and the execution compliance is at the bottom of their list of priorities. In the absence of this secondary data, structured and semi-structured interviews were used to obtain the primary data.

The structured interview questions were aimed to seek the views of people from the local dredging industry, dredging company, experts & administration as regards the effectiveness of mitigation of ecological impacts implemented in dredging and ways of improvement.

9.1 Demography of the Respondents

The majority of respondents are aged 18-24. Around 74% of respondents have a Master's or Bachelor's degree. 45 % of interviewees have dredging experience of 3-5 years.

9.2 Dredging Equipment, Process and Methods

Among all the river dredging equipment in Bangladesh, cutter suction dredgers are the most common. More than 73% of respondents know about these dredgers. The most common technique is cutter head (81%). The hydraulic mean is commonly used to raise dredged material to the surface. More than 91% of respondents use hydraulic pipelines to transport dredged material. The most preferred method of disposal of dredged material is to land (26.6%). In some cases, underwater discharge is used (10.1 %).

9.3 Awareness of Environmental Challenges & regulatory requirements

The survey measures respondent awareness of the environmental impacts of dredging. Notably, all respondents are aware of the ecological impacts, with 74% fully aware and 26% aware to some extent. 51% know about national or international pollution prevention laws, while 32% don't. MARPOL (49%) is the most widely known regulation, followed by national acts/regulations (29%). Notably, few people know about the LC, OSPAR, and IMO GHG strategies (11%).

9.3.1 Ecological, Legislation, Challenges, EIA and Risk Assessment Awareness

Dredge material pollution, air pollution, garbage (plastic) and noise are the four significant ecological mitigation measures being considered in the project stages or work scope. Only 39% of professionals say formal EIA or environmental risk assessment is done during the project design stage. Only 39% of stakeholders complete standard EIA & ERM at the design stage, and 45% are unaware of it, while 16% have never done it.

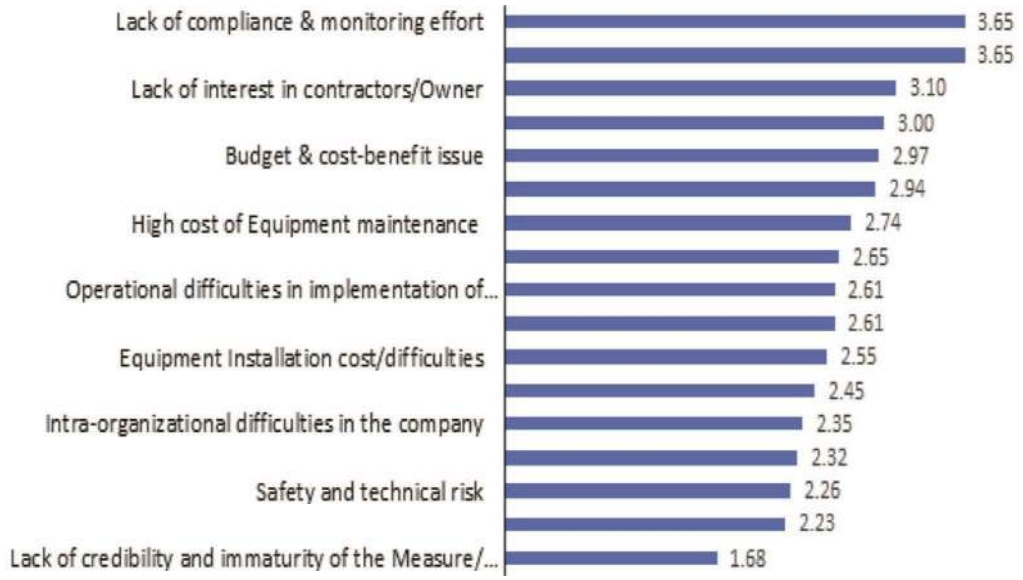

Figure 1: Barriers on Implementations

9.4 Barriers to Implementations

Stakeholders' perceptions are being quantified on the significance level of barriers to implementing environmental impacts reduction measures using Likert scale 1 to 5 (Not significant to very significant).

9.5 Pollution Prevention

The study finds out what are the forces that respondent anticipates driving them towards sustainable dredging. About 65% of professional states that either they do not face obligation for compliance with any internal or external bodies or they are not aware.

Only 35% of the respondent think the other way. Among those respondents, only 28% are obliged to take mitigation measures through project EIA. National Policies and Acts (65%) are seen as the most preferred method for implementing sustainable measures followed by enforcement from Regulators/Administrators (20%) and contractual bindings (10%).

9.6 Mitigation of Environmental Impacts and Improving Energy Efficiency

The study reveals existing practices on pollution prevention, energy-efficient operation, and emission reduction measures and monitoring. Only 16% of the dredging

company/projects have written procedures for mitigating environmental issues, and among them, about 60 % state that these are included in EIA or Project ecological management plan. Only 48 % of respondents have formal training, of which 39% is from in house training. Of these training programs, 55% are related to efficient dredge operations, and only 10 % are related to pollution prevention. Only 16% of the respondent's state that they have a dedicated Personnel Department or allocated staff time to look after the pollution prevention matters. 13% of the respondent companies participated in voluntary pollution prevention-related programs, and the most adopted voluntary program is ISO 140001:2015 (Environmental management system) . Only 16 % of respondents used some technological innovation for improving dredging efficiency, monitoring and pollution prevention and among that Data logger & positioning system most common. We can see that only 26 % of respondent states that monitoring of environmental goals is carried out in different stages of dredging, while 61 % states none or not aware. Most of the monitoring is carried out by the project owner (50%).

9.7 Ranking of operational best practices In terms of implementation

Figure 2 illustrates the typical best practices that have been implemented by more than 50% of respondents, though most of them being operational measures and some are technical. Monitoring engine performance, pipe leakage, correct size pipes, using dredged material for beneficial use are the most popular. At the same time, implementing adaptive & environmental management systems and having oil spill emergency plan /waste management are the lowest implementation.

9.8 Research PEST Analysis

Figure 26 illustrates PEST analysis of sustainable dredging barriers integrated with fish bone root cause analysis.

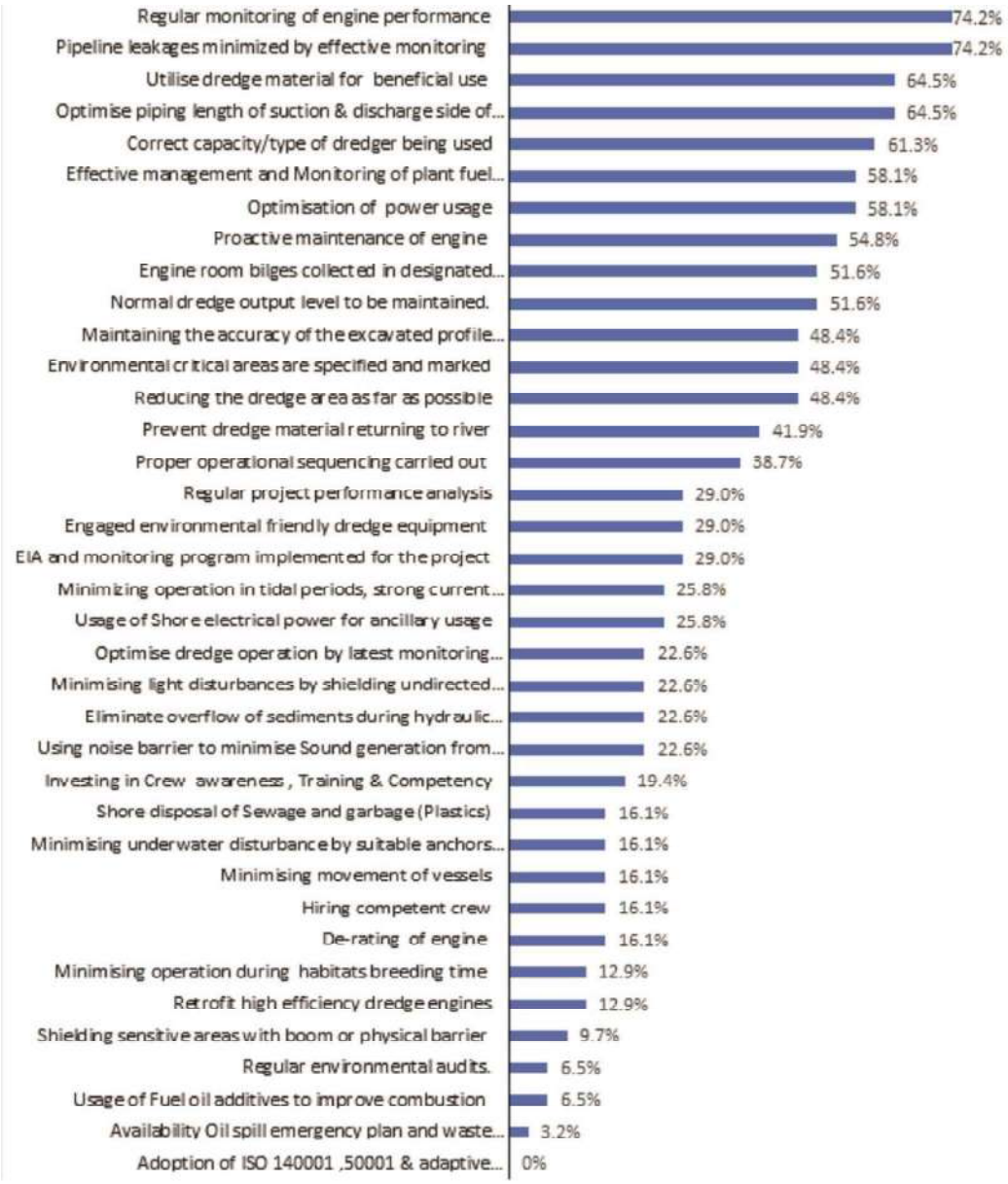

Figure 2: Ranking of Operational Best Practices in Terms of Implementation

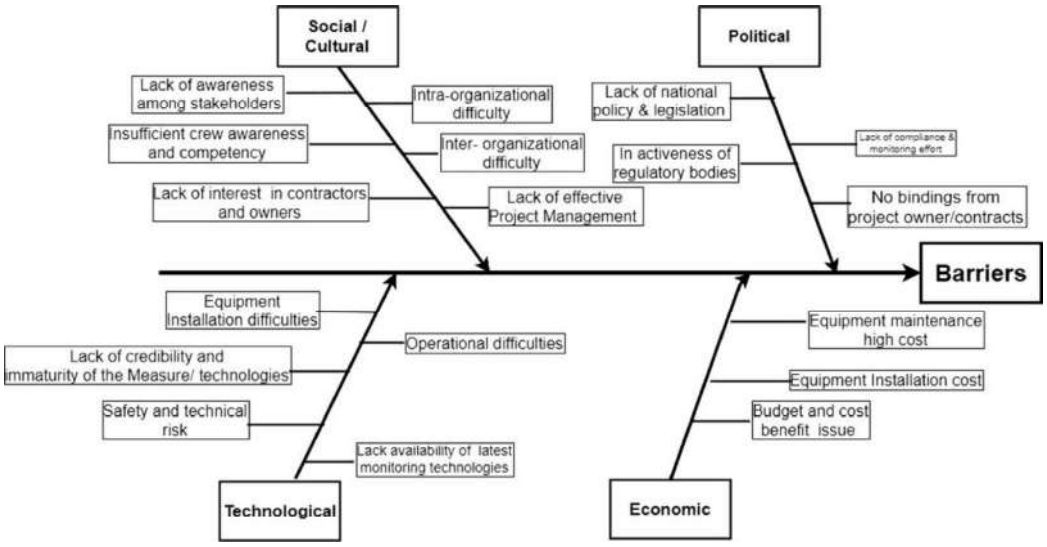

Figure 3: Research Pest Analysis

10. Conclusions

Execution is key to the effectiveness of all measures. The series of best practices and the implementation barriers need to be addressed following a systematic framework of improvement measures.

(i) Solutions to Social and Cultural Barriers

Potential solutions include mainly but not limited to only awareness training of the dredge crew, supervisor and managers, arranging seminars, workshops, training of the stakeholders by the local administration of the country, attending MET institution for training on dredging and mandatory competency certification requirement for dredge crew.

(ii) Solutions to Political Barriers – Lack of Legislation or Policy or Act

Potential solutions include mainly but are not limited to the formation and implementation of eco-friendly dredging and energy efficiency policy, ensuring environmental impact mitigation, stakeholders awareness building, effective monitoring, encouraging green dredging through incentives and compulsory EIA prior to the commencement of any projects irrespective of project size.

(iii) Solutions to Technological Barriers

Potential solutions are not just limited to only upskilling the dredge crews, supervisors, technical managers with the supervision of the national and international experts or equipment vendors on the operational measures, giving incentives for eco-friendly dredge and equipment deployment, correcting capacity of a dredger to be used and customising dredgers for local narrow and shallow waters.

(iv) Solutions to Organizational Culture Barriers

Potential solutions include awareness training on the environmental challenge, adoption of the adaptive management system, ISO 140001, ISO 50001 standards, and separating resources for environmental activities like training, dedicated personnel and budget.

(v) Solutions to Financial Barriers

Potential solutions include financial budgeting for environmental activities, giving incentives for deployment of eco-friendly dredgers, equipment, and monitoring, easing the process of sourcing of financial support from governments, banks or financial institutions.

(vi) Solutions to Effective Monitoring and Management Barriers

Potential solutions are mainly but just limited to the formation and implementation of dredging policy, making EIA compulsory for all projects and increasing the monitoring jobs in dredging tasks and carrying out regular environmental audits.

With the development of new technologies, the improvement measures need to be adjusted accordingly. Further research will contribute more to developing the dredging industry keeping it tuned up with the environment and ecological diversities. Carrying out joint research with international organisations will help sort out more pragmatic and effective measures to improve environmental practices. For example, reducing GHG emission by application of new low carbon energy sources, usage of data analytics, automation, developing an in-depth regulatory framework for dredging in line with international conventions like the London Protocol are the untapped areas for research.

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