Working togther toward sustainable sand mining and management.

WWF

Supported by:
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
based on a decision of the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

ECONOMIC VIABILITY OF SELECT AGGREGATES FOR THE CONSTRUCTION SECTOR

LOT 2: FINAL REPORT

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium International for World Wide Fund for Nature – Viet Nam (WWF-Viet Nam)] under the contract titled 'Consultancy service involving an assessment of the economic viability (profitability calculation) of select aggregates for the construction sector'.

This report is conducted by the Alluvium International and reflects the results of Alluvium International's research activities within the scope of the Project Drifting Sands: Mitigating the impacts of climate change in the Mekong Delta through public and private sector engagement in the sand industry" (IKI SMP), and Alluvium International's knowledge and expertise. The IKI SMP is managed by the Viet Nam Disaster and Dyke Management Authority, Ministry of Agriculture and Rural Development (VNDDMA) and the World Wide Fund for Nature in Viet Nam (WWF-Viet Nam) with the generous support of the International Climate Initiative (IKI), Germany. The contents of this report do not necessarily reflect the views of VNDDMA, IKI or WWF-Viet Nam. The degree of reliance placed upon the projections in this report is a matter for that reader's own judgement. The VNDDMA, IKI, WWF-Viet Nam and Alluvium International accept no responsibility whatsoever for any loss or conflicts occasioned by any person or organisation acting or refraining from action as a result of reliance on the study.

Authors: Boris Lam, James Binney, Dr Abbas Naqvi

Cover image: abstract river image, Shutterstock

© WWF-Viet Nam

CONTENTS

FIGURES

TABLES

ACRONYMS

ASEAN	Association of Southeast Asian Nations
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
GDP	Gross domestic product
GSO	General Statistics Office
HCMC	HCMC Chi Minh City
M-Sand	Manufactured sand
NPB	Net present benefit
NPC	Net present costs
NPV	Net present value
SBV	State Bank of Viet Nam
SLR	Sea-level rise
VIBM	Viet Nam institute for building materials
VMD	Vietnamese Mekong Delta

© WWF-Viet Nam

EXECUTIVE SUMMARY

This report investigates the economic viability of using alternative aggregates to replace river sand extraction in Vietnam's Mekong Delta (VMD). Excessive sand mining poses a significant threat to the environment, causing erosion, land subsidence, and saltwater intrusion. Furthermore, available sand mining resources will diminish over time, increasing their costs, and accelerating the need to move toward sustainable substitutes such as alternative aggregates.

The availability of 8 alternative aggregates were investigated in an earlier WWF study. Of these alternatives, manufactured sand (M-sand) was the most promising alternative. Recycled concrete had some potential, but there was limited evidence that it could provide sufficient volume in the short term to lift the pressure on sand excavation in the Delta. Additional assumptions are made on the estimated production volumes. There was insufficient data to suggest that the 6 alternatives were viable substitutes for river sand.

A high-level cost-benefit analysis (CBA) over a 20-year evaluation period was conducted to investigate the economic viability of adopting alternative aggregates to replace river sand mining. There were eight alternative aggregates considered. M-Sand (manufactured sand) and recycled concrete and demolition waste had the most potential based on existing literature on potential volumes that could be generated.

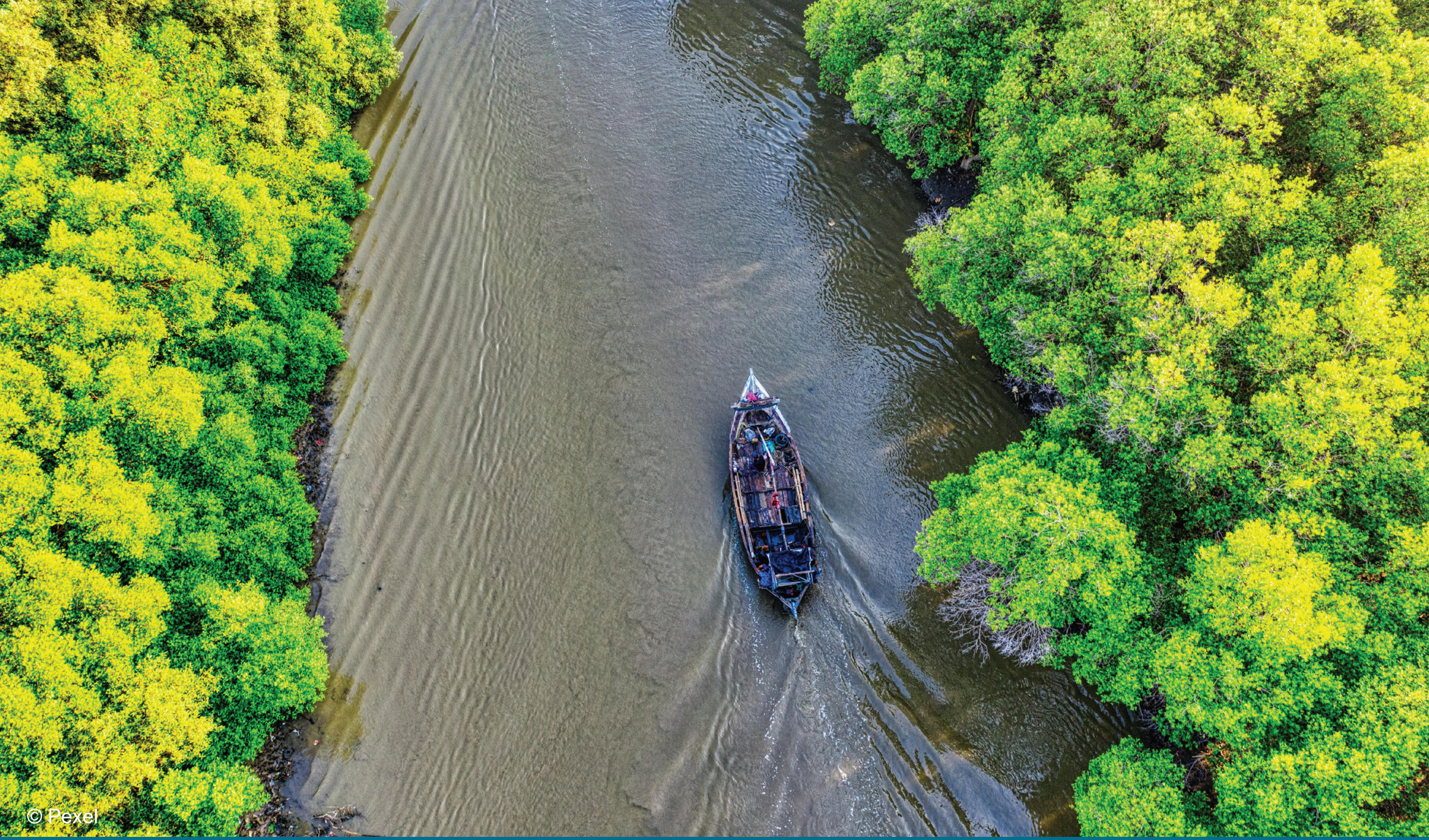
The key benefits that were modelled included cost savings from the unit price difference between river sand and alternative aggregates, avoided expenditure on bank stabilisation infrastructure, and avoided losses to agricultural productivity.

The modelled costs are the logistical costs of transporting materials, the operational costs of mining and processing alternative materials, compared to the capital expenditure of establishing a concrete recycling plant (as an alternative source of materials).

The modelled benefits are the avoided costs of riverbank stabilisation infrastructure, avoided losses in rice farming productivity, and cost savings to the construction sector.

The results of the economic analysis suggest that for every USD 1 invested, there are beneficial returns of USD 1.27. The total net present value of this is USD -0.08 B to USD 0.70 B. While the economic benefits of shifting to alternative aggregates appear modest based on the scope of benefits quantified, the environmental benefits could be substantial. In effect, these results are conservative and underestimate the true economic benefits of using alternative aggregates. Further research is needed to refine cost estimates and explore long-term viability of recycled concrete as a viable alternative.

The next steps from this study are to conduct a more detailed economic analysis with improved data on production volumes, logistical costs, and future demand, investigate the technical feasibility and environmental impact of using recycled concrete on a larger scale and evaluate potential policy responses to encourage the adoption of alternative aggregates in the construction sector.



1. INTRODUCTION

The Vietnamese Mekong Delta (VMD) is under immense pressure from various climate and human activities on the VMD's key natural assets and the ecosystem services they provide. Without significant transformative action within the next three decades, its future is threatened.

Major civil projects (e.g., dams) and the development of expanding urban areas all require significant volumes of aggregates (rock, sand, etc.) and the extraction of these materials from the VMD is already having an impact on river flow. Land subsidence, reduced sediment flow, erosion, rising tides, saltwater intrusion, increased flooding (particularly urban), and biodiversity loss put Vietnam's food security and sustainable development at risk. Many of these risks are at least partially attributable to the extraction of aggregates.

This project builds on previous and current work to undertake a physical assessment of stocks and extraction/production potentials of sustainable alternative sources to river sand. Specifically, the objectives are to:

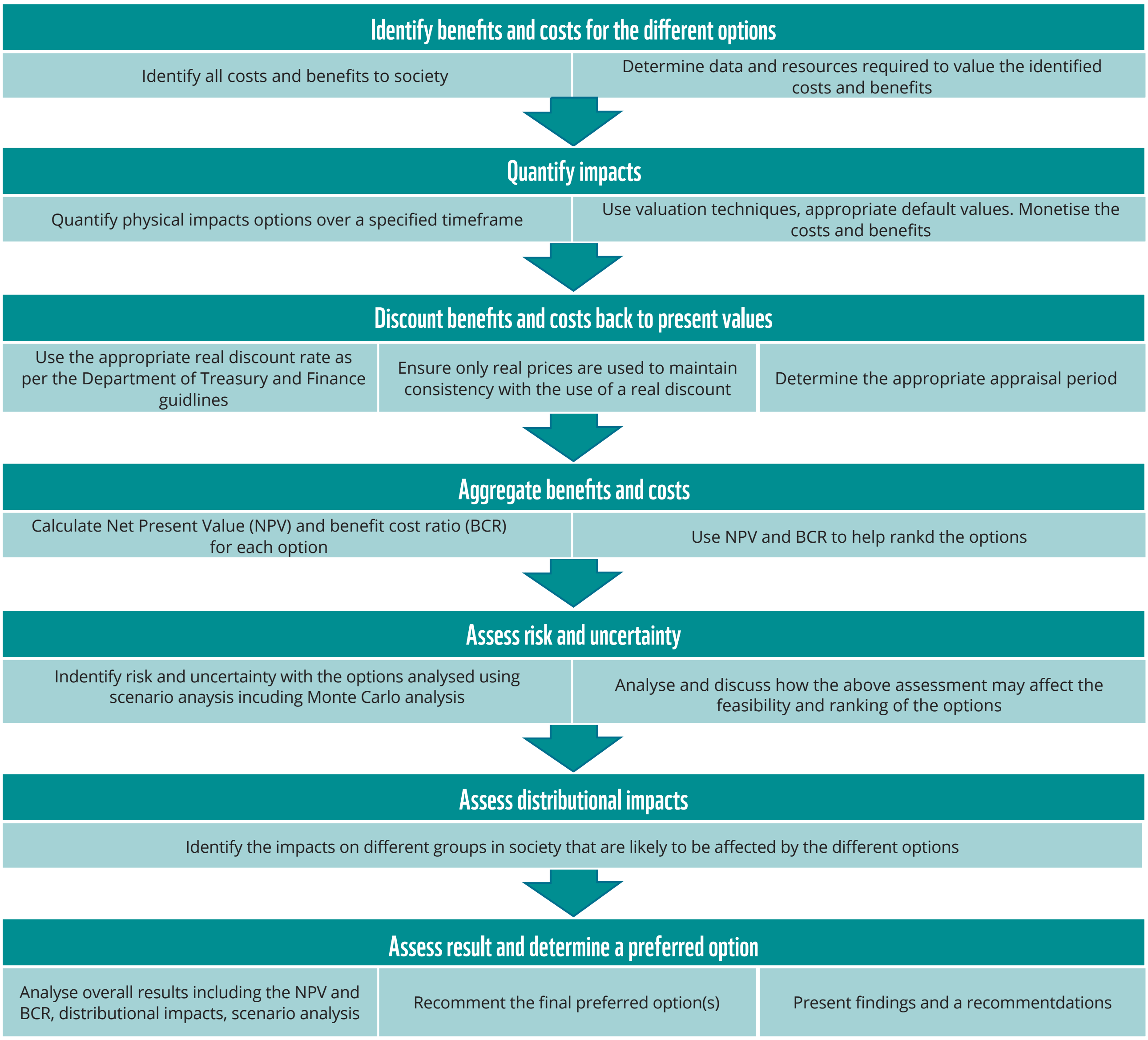
- Assess the economic viability of select alternatives to river sand that could meet the needs of the construction sector in Southern Vietnam. This should include an understanding of the volumes and types of aggregates required by the market and the relative costs of alternatives to river sand.
- Provide information and insight to Government decision makers (including issuers of permits), the construction sector and other stakeholders on the costs, risks, and benefits of using alternative sources of aggregates.

Deltares JV (2023) estimates that the current stock of existing mobile sand in the delta to be 367 to 550 Mm3 and is estimated to be sufficient to last a decade at current extraction rates of 35 to 55 Mm3 per year.[1] Based on the literature review, current demand for aggregates far exceeds sustainable extraction limits. In the medium to longer term, alternative sources of aggregates will be required to meet market demand. These are likely to be more costly.

1.1 CBA OVERVIEW

The approach taken to estimate the economic viability of drawing on alternate aggregates is a cost-benefit analysis (CBA). This approach assesses the net benefits of a new project or option, where the net benefits are assessed and estimated – all compared to a base case (sometimes called a do nothing differently case). The CBA approach can assess the long-term benefits and costs. The approach includes specific decision rules to indicate if a proposed project or policy provides net benefits (benefits are greater than costs over the long-term) and which option might be the most cost effective (based on the ratio of benefits to costs). Undertaking a CBA involves a series of structured phases and approaches. These are outlined in the figure below:

Figure 1. Typical phases of a CBA



1 Deltares Joint Ventures. (2023). Summary Report: Sand Budget for the Mekong Delta.

DISCOUNT RATE

A key parameter for the CBA is the discount rate. It reflects the time value of money and enables a conversion of future costs and benefits into current day values. The discount rate represents the expected return on the next best investment and reflects the cost of using resources in the project being analysed. Guidance around appropriate discount rates to use in CBAs are usually provided by government central economic agencies. State Bank of Vietnam does not provide guidance around the appropriate social discount rate to use in assessing economic feasibility. For the purposes of this analysis, the discount rate is set to 10-12% following World Bank conventional practice.[2] A 20-year evaluation period is selected for the economic modelling to match the understood economic life of major facilities that would be required to manufacture alterative aggregates.

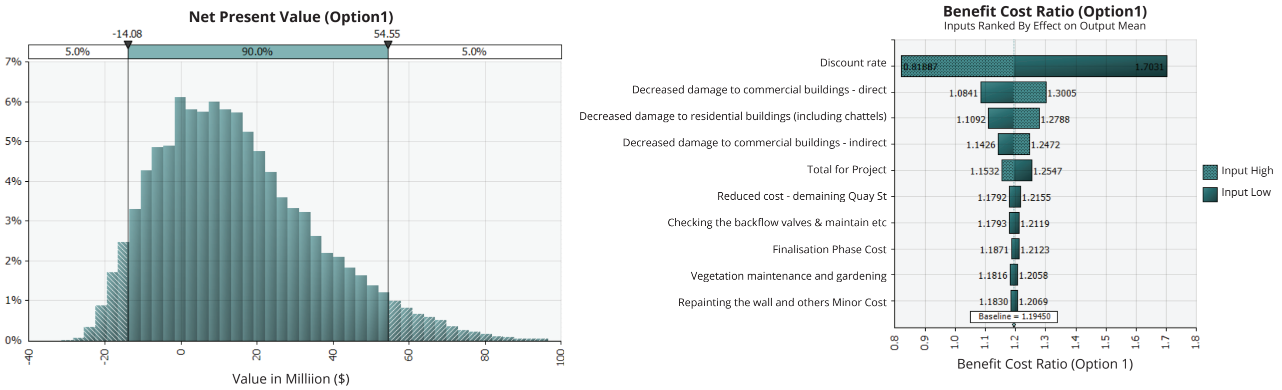
ADJUSTING UNIT VALUES TO PRESENT DAY TERMS

In conducting the economic analysis, cost and price data are drawn from multiple studies that are conducted in previous years. This data is scaled to present day terms (2024) by adjusting for inflation. Inflation data is taken from Viet Nam's General Statistics Office (GSO).

SENSITIVITY ANALYSIS

The CBA modelling includes a range of input variables for each key parameter. Within the CBA modelling, sensitivity analysis has been undertaken to understand key drivers of variability in the results. This sensitivity analysis will be undertaken using Monte Carlo simulations.[3] The outputs from the Monte Carlo simulations provide insight such as the impact of the range of input costs assumptions on the final assessment of options. An example of Monte Carlo simulation outputs is shown in the figure below. The analysis can also isolate which input assumptions and data account for the bulk of the risk and uncertainty, providing insight into which variables are most important for further investigation within subsequent detailed analysis of an options (e.g., within a detailed business case) or what variables require additional attention to managing risk (example on the right below).

Figure 2. Examples of Monte Carlo simulation outputs



KEY POINT

This CBA has a particular emphasis on the marginal (incremental) change in the costs of the alternative aggregate products for end use by the construction sector over the long-term.

2 Asian Developmental Bank. (2013). Cost-Benefit Analysis for Development. A practical guide.

3 Monte Carlo Simulation uses probability distribution for modelling a stochastic or a random variable. Different probability distributions are used for modelling input variables such as normal, lognormal, uniform, and triangular. From probability distribution of input variable, different paths of outcome are generated. Compared to deterministic analysis, the Monte Carlo method provides a superior simulation of risk. It gives an idea of not only what outcome to expect but also the probability of occurrence of that outcome. It is also possible to model correlated input variables. For this project we intend to conduct 10,000 simulations for each key variable, assuming a triangular distribution (unless available data suggests a different distribution around the mean estimate).

1.2. CURRENT EXTRACTION AND DEMAND FOR AGGREGATES

As outlined in the introduction, a sand budget report conducted by Deltares Joint Ventures (2023) details that that at the current extraction rate of 35 to 55Mm3 per year, and these reserves of mobile sand stock are projected to be depleted within a decade. This finding aligns with other existing literature, which indicates that the demand for aggregates significantly outstrips sustainable extraction limits in the region.[4] This can be pushed out to 2040 if current rates of extraction are reduced by 5%.

Forecasting future demand for aggregates is a complex exercise, and a detailed bottom-up approach can be used based on forecasts of construction development of major civil engineering works, road construction, land reclamation etc.[5] However, this is a resource heavy process and is unachievable under the constraints of this project. Jim O'Brien CSR Consulting (2021) reports that river sand makes up approximately 30% of total aggregate demand in the region.[6]

Future demand for aggregates is assumed to rise alongside economic and population growth. World Bank data shows an average annual real GDP per capita growth of 3.22% (ranging from 1.98 to 4.46%) for the past decade (2013-2022).[7] A growing economy with higher income per person (GDP per capita) will lead to increased spending on infrastructure projects and, consequently, greater demand for aggregates.

The Research Center for Resources and Rural Development (RECERD) were engaged by WWF-Viet Nam to conduct a value chain analysis of sand in the Vietnamese Mekong Delta. As part of that study they conducted a review of sand demand forecasts by Viet Nam's Ministry of Construction and Jim O'Brien consulting. A comparison between the forecasting approaches taken by the three different demand forecasts and this study is presented in Table 1. The table shows that there is significant variability in estimating the current demand of river sand. Part of this variation stems from different definitions of the scope of use of sand and different estimation procedures. This study has assumed that current demand for sand in the present day is around 60 MT based on current extraction rates of river sand as reported in Deltares Joint Ventures (2023), and increases along with population growth over time. To the extent that this current estimate is an underestimate due to unauthorised extraction, the volume of the potential market for M-Sand will be higher and the timing of the exhaustion of existing stockpiles will be sooner. Both of these factors are more favourable for the commercial production of M-Sand going forward.

4 Hackney, C. R., Darby, S. E., Parsons, D. R., Leyland, J., Best, J. L., Aalto, R., Nicholas, A. P., & Houseago, R. C. (2020). River bank instability from unsustainable sand mining in the lower Mekong River. Nature Sustainability, 3(3), 217-225.

5 Smith, G. (2017). Estimation of the demand for construction aggregate. Natural resource modelling, 30(4), e12144.

6 Jim O'Brien CSR Consulting. (2021). Analysis of and lessons learned on sand and gravel extraction policies, regulations and practices in international river basins.

7 World Bank Group. (2024). GDP growth (annual %) - Viet Nam. 2013 - 2022.

Table 1. Estimated demand for river sand for construction and levelling in the present day from different estimation approaches

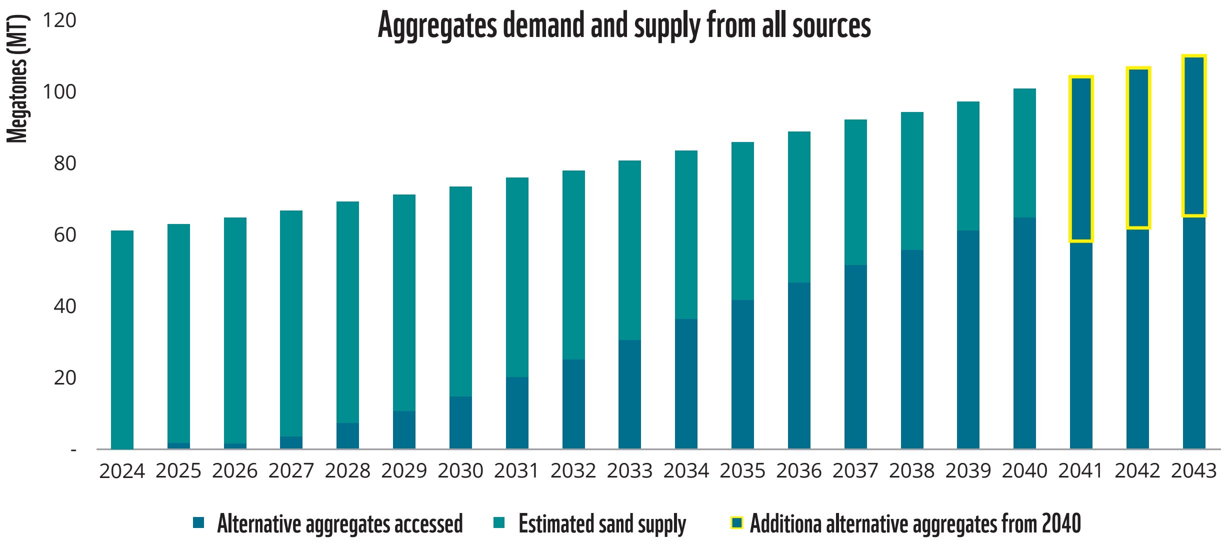
Report	Forecasted demand in the present day (tonnes per annum)	Consideration for construction and/or levelling
Research Center for Resources and Rural Development	101 MT	Construction and levelling
Ministry of Construction	36 MT	Only construction demand
Jim O'Brien Consulting	24 MT	Only construction demand
Alluvium	60 MT	Implied construction and levelling demand based current extraction figures from Deltares Joint Ventures (2023).

Note: The forecasting approach adopted in this study considers population growth as the main driver of aggregate demand. This implicitly considers a variety of different drivers such as urban development, large infrastructure projects, and other civil uses as contributing to the increase in the demand for aggregates. Although levelling demand for highway construction is not considered explicitly in this analysis, data from the Ministry of Construction suggests that the demand for aggregates averages approximately 10 MT per year for a 5-year period (totalling 50MT).[8] The impact of this demand is captured within sensitivity analysis and current modelled demand estimates.

The forecasted future demand for total aggregates based on the approach taken in this study is presented in Figure 3. It is projected that by 2043, the demand for aggregates will increase by 83% compared to the present day. Demand by 2043 based on this method is estimated at 158 M tonnes for the Viet Nam Delta.

The diagram additionally illustrates the breakdown of annual supply between river and and alternative aggregates. The proportion of alternative aggregates compared to river sand supply grows gradually over time, as this reflects the declining availability of river sand and the increasing volume of alternative aggregates. From 2040 onwards where river sand is depleted based on current extraction rates, this supply will have to come entirely from alternative aggregate supply or from imports.

Figure 3. Demand and supply of aggregates



8 Ministry of Construction. (2022). Decision No. 287/QD-TTg dated Feb 28 2022 for approval for planning for development of the Mekong delta region for the 2021 – 2030 period with vision towards 2050

AVAILABILITY OF ALTERNATIVE AGGREGATES TO REPLACE RIVER SAND MINING

The select group of aggregates considered under investigation as substitutes for river sand are:

1. **M-Sand,**
2. **Rice-husk ash,**
3. **Sugarcane bagasse ash,**
4. **Recycled concrete,**
5. **Glass waste,**
6. **Blast furnace slag,**
7. **Rubber waste (waste tyres); and,**
8. **Coal bottom ash**

The availability of these alternative aggregates are presented in VIBM (2023).[9] In that report, field surveys were conducted to evaluate the viability of the eight more sustainable alternates to river sand above as replacement materials for river sand in the construction sectors in 13 provinces cities (12 Provinces and 1 city in the Mekong Delta and Ho Chi Minh City).[10] The analysis considered current production volume, available reserves, maximum productive capacity, technological capability, and quality based on adherence to technical manufacturing guidelines.

Not all relevant information was made available by the manufacturers that were surveyed. As a result, assumptions were made to estimate the production capacity and remaining reserves available to be mined to fill the gaps in the data. Given the significant uncertainty around these estimates, this variation was accounted for in the sensitivity analysis.

In modelling the viability of alternate aggregates to replace the demand for river sand, the prospective change in additional output capacity is evaluated as current output volumes are already used for concrete generation in the status quo. Under the base case, the production of aggregates is assumed to remain at their current levels. In the alternative scenarios (alternative aggregates are manufactured), it is assumed that construction facilities will scale up production of aggregates to satisfy demand to replace river sand. The shaded area in the figure represents the increase in these potential volumes.

Although there may also be an increase in current the rate of production under the base case, there is insufficient information to identify what this increase might be.

The key findings from the VIBM (2023) report are summarised as follows:

M-SAND

- M-Sand was identified as the best substitute for river sand with similar quality.
- M-Sand production can be scaled up to account for increasing demand in the short and medium term.
- There may be insufficient reserves of M-Sand for long-term extraction (>10 years).
- Of the 9 sand crushing companies surveyed, one of them does not produce crushed sand of adequate quality to be considered. This represents a reduction of approximately 11.7 M tonnes of potential M-Sand availability.

RECYCLED CONCRETE

- Sources of recycled concrete are old structures such as flats, houses, and industrial construction that can be demolished or refurbished.
- Data from the Viet Nam's Department of Construction suggests that there over 2,500 flats, 2 billion square meters of construction space, and 500 houses where concrete for recycling could be sourced.

9 Viet Nam Institute for Building Materials [VIBM]. (2023). Consultancy service involving an assessment of stocks and extraction/production potentials of sustainable alternative sources to river sand (LOT 1B) Code: 40001883/402576/518351

10 The 13 Mekong Delta cities are Tan An, My Tho, Can Tho, Ben Tre, Vinh Long, Tra Vinh, Cao Lang, Soc Trang, Long Xuyen, Rach Gia, Vi Thanh, Bac Lieu, and Ca Mau in addition to Ho Chi Minh City.

- There were 3 companies surveyed, and only 1 provided concrete recycling capabilities, the other 2 companies were only capable of dismantling and transporting construction waste.
- A state-owned enterprise, CITENCO is currently involved in the gathering and management of building debris in HCMC. As of the time of reporting, it is in the process of developing a building debris and waste recycling centre. Survey results show that current volumes of construction waste are insufficient to replace river sand.
- Construction of the Building Waste Recycling Centre at the North West Solid Waste Treatment Centre by CITENCO is underway, no additional information was provided. A web search was done to supplement this information (see Box 1).
- Data collation by CITENCO finds that pre-pandemic production of construction demolition waste was estimated at 1,300 tonnes per day, with post-pandemic production falling drastically to 170 tonnes per day.
- Projections based on studies from developed nations suggest that there will be a significant increase in demolition waste when high rise structures in Ho Chi Minh City and the surrounding areas are taken down. This trend is expected to begin around 2040.

BOX 1. SUPPLEMENTARY RESEARCH TO ESTIMATE POTENTIAL RECYCLING OF CONCRETE AND DEMOLITION WASTE.

VIBM (2023) did not forecast the availability of construction waste to be recycled into aggregates as they have deemed that the current volume of supply to be insufficient in the short and medium term. Based on a web search:

The site is located in Cu Chi, HCMC. This is approximately 37 km away from HCMC.11 It is unclear whether the facility will be equipped to manage and recycle construction and demolition waste. Consequently, it is assumed that there will be additional upgrades required. Based on analysis by Hoang et al. (2021), the capital and operational costs are USD 3.50 per tonne and USD 4.03 per tonne, respectively.12

The Northwest facility has a reported capacity of 2,000 tons per day (500,000 tonnes per year, assuming a 300-day working calendar year).13 It is assumed that the demolition and concrete waste recycling facility will have a capacity of 250,000, and the price of the recycled concrete aggregate to be similar to that of M-Sand.

11 Asian Development Bank [ADB]. (2003). Summary Initial Environmental Examination. Ho Chi Minh City Environmental Improvement Project. Accessed at https://www.adb.org/sites/default/files/project-documents//vie-ho-chi-minh.pdf

12 Hoang, N. H., Ishigaki, T., Kubota, R., Tong, T. K., Nguyen, T. T., Nguyen, H. G., ... & Kawamoto, K. (2021). Financial and economic evaluation of construction and demolition waste recycling in Hanoi, Vietnam. Waste Management, 131, 294-304.

13 https://en.sggp.org.vn/waste-treatment-project-stagnant-due-to-complicated-procedures-post101058.html


© Pexel

OTHER POTENTIAL AGGREGATES

Overall, there was little information available on the potential additional generation of the other 6 aggregates that could serve to replace river sand.

- The volumes of glass waste are too small to be considered as a substitute. Further, current glass waste is gathered and exported to China or recycled domestically into new glass.
- Over 200 km separates blast furnace slag factories from the major urban areas in the Mekong Delta. Additionally, there is no additional stock available to be sourced as the factory surveyed already sells all its inventory to cement manufacturers, mills, and mixing stations.
- Rubber waste is processed through pyrolysis and transformed into fuel after refinement. This is out of scope for the analysis as it is not used as a construction material.
- Reserves for coal bottom ash were considered too low to be a viable substitute.

KEY POINT

The availability of 8 alternative aggregates were investigated in the preceding project. Of these alternatives, manufactured sand was the most promising alternative. Recycled concrete had some potential, but there was limited evidence that it could provide sufficient volume in the short term to lift the pressure on sand excavation in the Delta. Additional assumptions are made on the estimated production volumes. There was insufficient data to suggest that the 6 alternatives were viable substitutes for river sand.

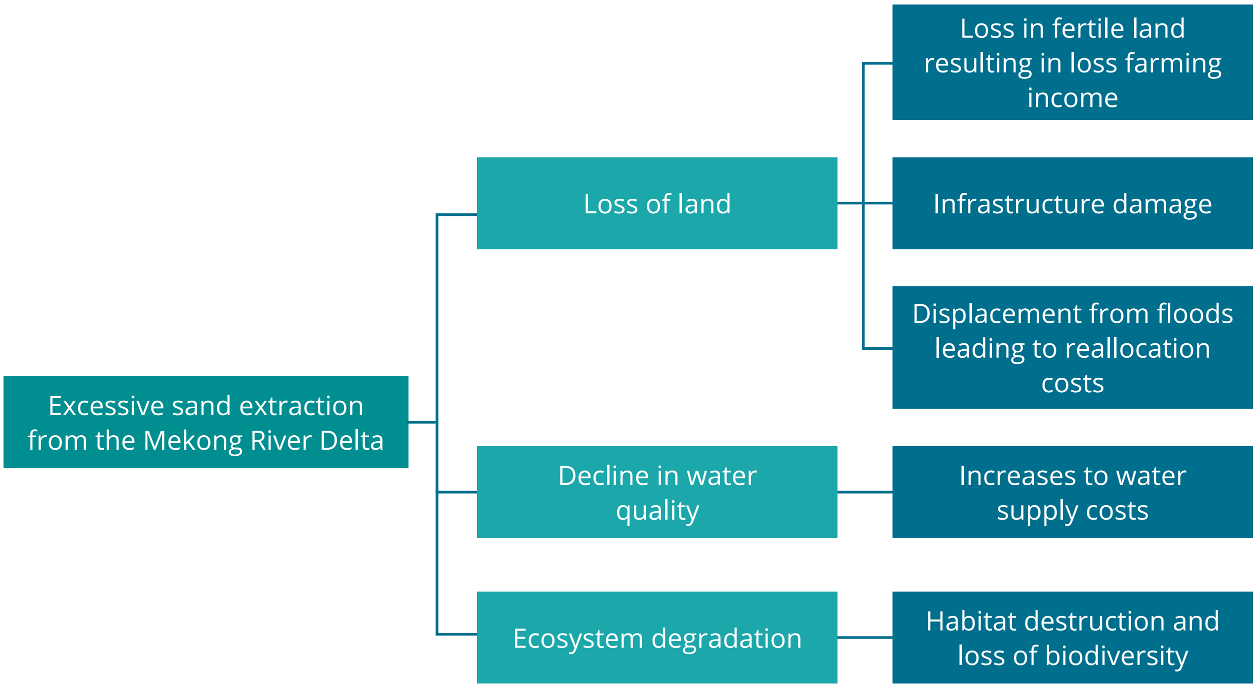

© WWF-Viet Nam

2. COSTS AND BENEFITS OF ALTERNATIVE AGGREGATES

A rapid review of reports shared by WWF-VN and other relevant reporting obtained through a web search was conducted. This review scopes out which benefits and costs can be quantified in the CBA. Major impacts that are not quantified in this report are discussed qualitatively in Section 3.4.

Widespread extraction of sand and gravel from the Mekong River Delta broadly leads to four impacts that are considered in this scope of this study. These are illustrated in the diagram below.

Figure 4. Summary of impacts of excessive sand and gravel extraction



The excessive extraction of sand from the Mekong River poses a significant threat to the VMD due to its detrimental impact on both the physical environment and the aquatic ecosystem. This practice leads to substantial erosion, resulting in land subsidence and a loss of precious land area. Moreover, it disrupts the delicate balance of the aquatic ecosystem, potentially jeopardizing the sustainability of fish populations and other aquatic life.

Switching to an alternative source of aggregates rather than continuing sand extraction from the Mekong River presents a potentially viable solution to mitigate these negative impacts. By adopting this approach, the VMD could experience a reduction in erosion, safeguarding its land area and infrastructure. Additionally, it could contribute to the preservation of the aquatic ecosystem, ensuring the long-term sustainability of its resources. These avoided damages resulting from a shift to alternative aggregates can be considered benefits associated with this proposed change.

Transitioning to a new source of aggregates entails costs such as the capital expenditure on establishing a new demolition waste recycling facility, the operational expenditure of processing demolition waste and manufacturing M-Sand, and the incremental change in logistical costs of transporting these products between facilities and their destination.

KEY POINTS

This CBA will have a particular emphasis on the marginal (incremental) change in the costs of the alternative aggregate products for end use by the construction sector.

There are other significant benefits, however, the availability of robust data to value those benefits are limited.

2.1. COSTS AND BENEFITS IN SCOPE OF THE ASSESSMENT

There are several impacts that are considered in the CBA. However, not all impacts can be valued in monetary terms and included in the quantitative analysis/CBA modelling due to data and information limitations. The table below outlines the key impacts assessed and how they are treated in the CBA – both in terms of their inclusion in the base case, and their inclusion in the manufactured aggregates case.

Table 2. Scope of assessment in quantitative modelling

Inclusion and section of this report	Treatment in base case	Manufactured aggregates case	Comments
Riverbank Erosion/ Collapse (Section 2.2)	Riverbank erosion (a cost).	Avoided expenditure on riverbank stabilisation infrastructure (a benefit)	Included in quantitative CBA modelling. Significant quantitative sensitivity conducted. This is primarily a direct impact on affected landholders and an indirect impact on the broader community.
Impacts on agricultural productivity (Section 2.3)	Lost agricultural productivity due to salt intrusion (a cost).	Reduced losses in agricultural productivity due to salt intrusion (a benefit).	Included in quantitative CBA modelling. Significant quantitative sensitivity conducted. This is primarily a direct impact on affected landholders and an indirect impact on the broader community.
Impacts of use of manufactured aggregates on commercial operations (Section 2.4)	No change to current practice.	For the potential volume of manufactured aggregates produced, change in net costs of production and transportation to end users. This includes full costs of manufacture and change sin logistics/transport costs (savings are a benefit)	Included in quantitative CBA modelling. Significant quantitative sensitivity conducted. This is primarily a direct impact on producers and users of aggregates.

These impacts are further assessed in the following sections.

2.2. EROSION AND SALINITY EFFECTS FROM EXCESSIVE SAND MINING

Broadly speaking, riverbed erosion in the VMD is primarily driven by (Deltares JV, 2023):

- Climate change induced sea-level rise.
- Groundwater extraction.
- Hydropower developments upstream trap sediment and reduces its flow downstream.
- Excessive sand mining.

COST OF EXCESSIVE EROSION

Aggregate extraction is the primary contributor to bank and coastal erosion in the VMD. Analysis by Anthony et al. (2015) using high quality satellite imagery revead that over half of the delta's coastline, which stretches for more than 600 kilometers, has been eroding between 2003 and 2012. This erosion is even worse on the South East Sea coast, where nearly 90% of the shoreline is affected.[14] Hard infrastructure options will need to be constructed to stabilise the streambank to avoid riverbank collapse. Cost information shared by WWF from the Southern Institute of Water Resources Research (SIWRR) suggests that the average cost for vertical wall embankment works is USD 3.5 M per km.

Table 3. Riverbank infrastructure input data

Parameter	Unit	L	M	H
Cost of infrastructure options	USD M per km	2.84	3.54	4.27
Length of eroded riverbank in the Delta	Km	343	457	571
Impact of sand mining on riverbank erosion	% per annum	11	15	19

SALINITY INTRUSION

Riverbed erosion exacerbates salinity intrusion. Erosion deepens the riverbed, allowing more forceful tidal surges to propel saline water inland. It also reduces the river's downstream flow, weakening its ability to resist seawater. These factors combined lead to the inland advancement of saline conditions (Eslami et a., 2019).[15]

Research by Eslami et al. (2021) found that the area affected by salinity intrusion can increase by an additional 10 to 25% by 2050 from a combination of sand mining and groundwater extraction, with climate change adding an additional 6 to 19%.[16] This study does not report the effect of sand mining in isolation, and the majority of studies examined in the literature review considers the net effect of

14 E. J., Brunier, G., Besset, M., Goichot, M., Dussouillez, P., & Nguyen, V. L. (2015). Linking rapid erosion of the Mekong River delta to human activities. Scientific reports, 5(1), 14745.

15 Eslami, S., Hoekstra, P., Nguyen Trung, N., Ahmed Kantoush, S., Van Binh, D., Duc Dung, D., Tho, T.Q., & van der Vegt, M. (2019). Tidal amplification and salt intrusion in the Mekong Delta driven by anthropogenic sediment starvation. Scientific reports, 9(1), 18746.

16 Eslami, S., Hoekstra, P., Minderhoud, P. S., Trung, N. N., Hoch, J. M., Sutanudjaja, E. H., Dung, D.D., Tho, T.Q., Voepel, H.E., Woillez, M.N., & van der Vegt, M. (2021). Projections of salt intrusion in a mega-delta under climatic and anthropogenic stressors. Communications Earth & Environment, 2(1), 142.

upstream sediment sand trapping and human activity downstream as a group, it is challenging to determine the erosion attributable to just sand mining activities. Given this uncertainty, it is assumed that sand mining contributes to 5-20% of salinity intrusion.

2.3. IMPACTS ON AGRICULTURAL PRODUCTIVITY

Changes in the climate and industry-related reductions in river flow (dam construction, water extraction, and sand mining) have increased the risk of saltwater intrusion in the VMD. This has led to increased salinity impacts for rice farmers in the region.

Excessive salinity directly threatens agricultural production, especially rice cultivation which is the predominant crop in the region. Rice is especially susceptible to excessive salinity during the seeding stage (Zeng and Shannon, 2000).[17] The months where they are expected to be especially susceptible to salinity intrusion will be during the floods from the monsoon season, from August to November. 70% of rice production in the VMD is exported overseas, accounting for 90% of national exports.[18] Damages to rice crop productivity can make these impacts economically significant.

Analysis by United States Department of Agriculture (USDA) finds that the average rice yield over 2019 to 2023 to be 6 tonnes per hectare.[19] Case studies conducted by Khai et al. (2018) on three salinity affected areas in Vietnam during 2015 to 2016 found that the annual rice yield loss from saltwater intrusion was estimated to be 2.5 to 4.05 tons per hectare, at average salinity levels of 0.8 to 2.8%.[20] Analysis by Nhan et al. (2012) on farm-level adaptation to salinity intrusion found that the threshold of converting rice cultivating to rice and shrimp rotational farming is at 4% salinity.[21] Projections by Eslami et al. (2021) show that under a RCP 8.5 carbon emissions scenario with land subsidence, there will be an 8% increase in salinity with an additional 162,000 hectares inundated relative to present day conditions, where present day conditions in the study were assumed to be 3.5%.

Although farmers can adopt to this through adopting salt-tolerant rice varieties (Paik et al., 2020), there is little robust evidence to suggest widescale uptake of these varieties and as such will not be considered in the modelling.

Figure 5 illustrates the areas impacted by inline saline intrusion from 2016 and 2020 that would impact on agricultural productivity. A report by the International Federation of Red Cross and Red Crescent Societies (IFRC, 2020) summarising data from the Central Steering Committee for Natural Disaster Prevention and Control (CCNDPC) estimated a loss of approximately 460,000 ha of productive area.[22] In 2020, the Disaster Management Authority estimated that approximately 58,000 ha of rice farming in the VMD were impacted.[23] The area impacted can vary significantly depending on a range of climactic and environmental conditions (e.g., changes to rainfall and runoff), and these two estimated are used in the sensitivity analysis with a central estimate being an average of the two values.

---

17 Zeng, L., & Shannon, M. C. (2000). Salinity effects on seedling growth and yield components of rice. Crop science, 40(4), 996-1003.

18 The Anh, D., Van Tinh, T., & Ngoc Vang, N. (2020). The domestic rice value chain in the Mekong Delta. White Gold: The Commercialisation of Rice Farming in the Lower Mekong Basin, 375-395.

19 United States Department of Agriculture [USDA]. Foreign Agricultural Service. Vietnam Rice Area, Yield and Production.

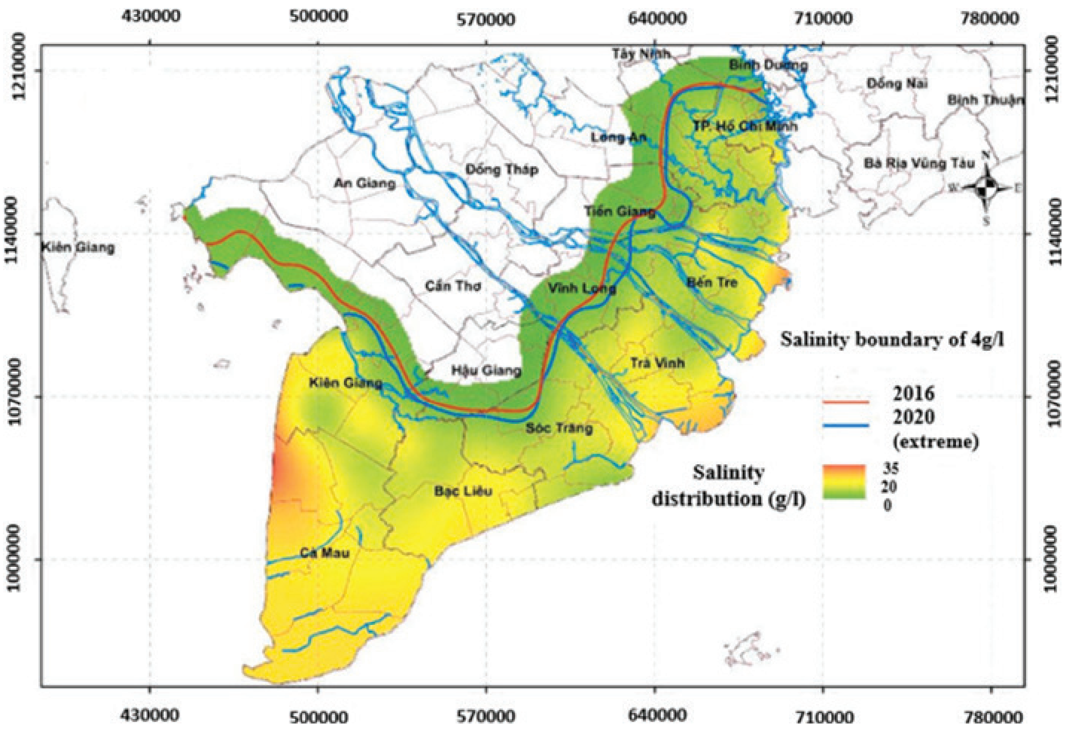
20 Khai, H. V., Dang, N. H., & Yabe, M. (2018). Impact of salinity intrusion on rice productivity in the Vietnamese Mekong Delta.

21 Nhan, D. K., Phap, V. A., Phuc, T. H., & Trung, N. H. (2012). Rice production response and technological measures to adapt to salinity intrusion in the coastal Mekong delta. Can Tho: Can Tho University.

22 International Federation of Red Cross and Red Crescent Societies [IFRC]. (2020). Viet Nam: Drought and saltwater intrusion.

23 Vietnam Disaster Management Authority. (2020). Overcoming the saltiest drought in history, lessons for the present and future. Accessed December 28, 2021.

Figure 5. Areas in the VMD affected by salinity intrusion from 2016 and 2020



Source: CCNDPC, 2020[24]

Table 4. Rice impacts input data

Parameter	Unit	L	M	H
Rice production area under risk of salinity intrusion	USD per tonne	10.15	13.54	16.92
Rice yield	tonne per hectares	5.40	6.00	6.60
Salinity intrusion impact on rice yields	tonne per hectares	2.50	3.28	4.05
Rice producer prices	USD per tonne	281.00	295.35	329.60

Source: FAOSTAT (2024), Khai et al. (2018), USDA (2024).

KEY POINT

The value of this benefit is measured in terms of the avoided loss of productivity associated with salinity intrusion and is estimated by multiplying against the value of agricultural production in the area loss.

24 Central Steering Committee for Natural Disaster Prevention and Control [CCNDPC[]. (2020). Report on Drought, Salinity Intrusion, Damage and Response Solutions.

2.4. IMPACTS OF USE OF MANUFACTURED AGGREGATES ON COMMERCIAL OPERATIONS

From the construction industry's viewpoint, the benefit of using alternative aggregates are the lower unit costs relative to river sand. VIBM (2023) reports that the price of M-Sand is USD 8.12 per tonne compared to the price of river sand at USD 13.54 per tonne. It is important to note that these reported prices are at the point of production assuming that the cost of transport would be similar, and the price differential of USD 5.42 represents a financial benefit to end users. This price differential may underestimate the benefits as the efficient location of M-Sand plants/mines would typically be close to the source of recyclable materials which will also be close to the source of final demand e.g., major cities and provinces.

Relative prices for M-Sand at two manufacturing locations were also provided WWF-Viet Nam, and this additional data was included in the sensitivity analysis. The relative prices of the various alternatives are presented in the table below.

Table 5. Aggregate price input data

Parameter	Unit	L	M	H
River sand	USD per tonne	10.15	13.54	16.92
Alternative aggregate (M-Sand)	USD per tonne	6.09	8.12	10.15

Source: VIBM (2023)
Note: M-Sand unit prices are used as a proxy for recycled concrete.

ADOPTION RATE OF ALTERNATIVE AGGREGATES

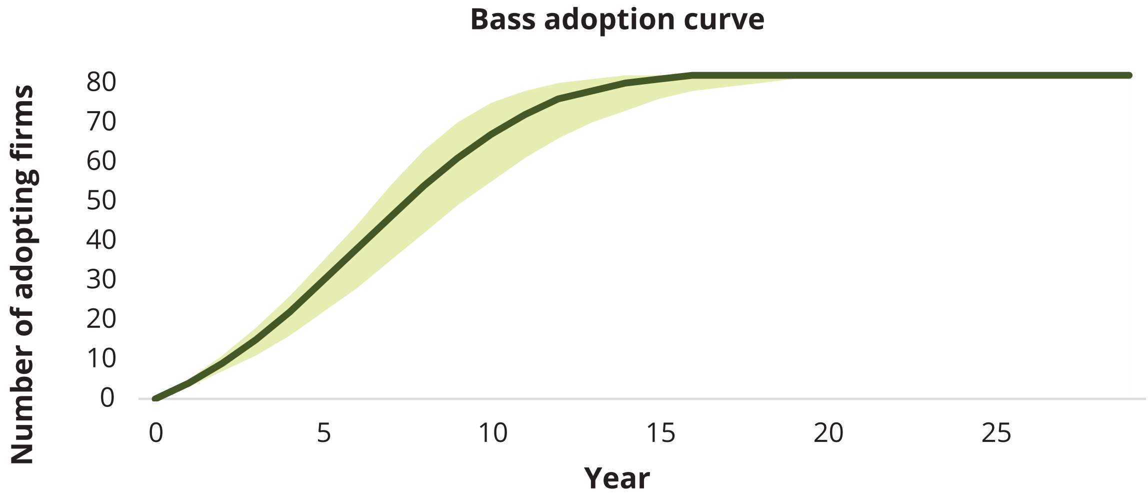
Not all potential producers of manufactured aggregates will commence production immediately, and the industry will take time to develop. Therefore, a Bass diffusion model is used to estimate how likely a firm will be to adopt an alternative technology or product (Bass, 1969).[25] It is used in this study as a simple method to scale down the number of licensed extractors that adopt alternative aggregates over time. The Bass diffusion model has been used extensively in a variety of fields and product categories. It is driven by two parameters, the influence of early adopters and the influence of social networks and imitating firms.

Given the limitations of this study, it is also assumed that the alternative aggregates are perfectly substitutable between each other. This simplification allows for the model's application despite data limitations. Differences in physical properties, quality, logistics, and suitability for different construction purposes can greatly influence the preferences of the construction industry. The assumption of substitutability between aggregates means that the construction sector can mitigate the risks associated with changes in supply or quality of a particular type of aggregate by switching between sources without significant impact to their operations.

25 Bass, F. M. (1969). A new product growth for model consumer durables. Management science, 15(5), 215-227.

The curve follows an S-shape, showing an initial slow growth period where there is slow market penetration of the alternative aggregates. Following this stage there is rapid growth due to influence of social networks. The final stage has a slowdown in uptake as the number of potential adopters' declines. The Bass diffusion curve that is used for this economic analysis is presented in Figure 6. The shaded area shows the impact of the variation in the Bass model's input parameters on the overall level of uptake. For this study, it is estimated that full adoption of aggregates takes place around year 15 of the analysis.

Figure 6. Bass diffusion curve



where:

Nt – number of adopters in year t,

Nt-1 – number of adopters in year t-1,

m – maximum number of adopters (82),

p – coefficient of innovation (0.2 +- 50%),

q – coefficient of imitation (0.283 +- 50%)

The potential range of values of p and q are selected in reference Kunovjanek and Reiner (2020) and Sultan et al. (1990) and accounted for in the sensitivity analysis.[26,27]

OPERATIONAL COSTS OF AGGREGATE PRODUCTION

As discussed in the section above on Recycled concrete, CAPEX and OPEX data is taken from an economic evaluation conducted by Hoang et al. (2021) on the viability of developing a construction and demolition waste recycling facility in Hanoi. In that study, the CAPEX elements included construction equipment and landfill occupation rates. The OPEX elements consider labour, maintenance, land renting, energy, disposal, input materials, and taxes.

While VIBM (2023) provides estimates of potential volumes and prices of M-Sand, there is no data available on the marginal costs of the manufacturing of M-Sand. In lieu of this data, the OPEX data from the Hoang et el. (2021) study is used as a proxy. There will be no additional CAPEX incurred for the estimates of M-Sand it is assumed that the mining companies already have the requisite infrastructure in place to scale up production. At an assumed capacity of 250,000 tonnes per annum, the estimated CAPEX for the facility will be approximately 870,000 USD. A 90% contingency cost buffer is added on top of this marginal difference to reflect additional uncertainty related to the figures that are used in the analysis.

26 Kunovjanek, M., & Reiner, G. (2020). How will the diffusion of additive manufacturing impact the raw material supply chain process?.International Journal of Production Research, 58(5), 1540-1554.

27 Sultan, F., Farley, J. U., & Lehmann, D. R. (1990). A meta-analysis of applications of diffusion models. Journal of marketing research, 27(1), 70-77.

Table 6. Operational and capital input data

Parameter	Unit	L	M	H
OPEX	USD per tonne	3.79	4.04	4.23
CAPEX	USD per tonne	2.98	3.50	4.01
CAPEX assuming a capacity of 250,000 tonnes per annum	M USD	0.75	0.88	1.00
90% CAPEX buffer	M USD	0.67	0.79	0.90
Modelled CAPEX assuming capacity of 250,000 tonnes per annum with additional 90% CAPEX buffer	M USD	1.42	1.67	1.90

Source: Hoang et al. (2021)

LOGISTICAL COSTS OF USE OF MANUFACTURED AGGREGATES

It is assumed that no additional vehicles are required to be purchased for transporting manufactured aggregates as existing vehicles will be redirected to collecting materials from alternative sources. This approach minimises the capital expenditure required. It is also assumed that the operator bears the full cost of returning without cargo, not the party receiving the shipment. With this assumption, the analysis accounts for the operational expenses incurred during return trips and only attributes the costs to the party responsible for managing the logistics. The marginal change in distance travelled is then the difference between travel to the facilities for the alternative aggregates and the Mekong Delta. These distances are drawn from VIBM (2023).

Table 7. Average travel distance between M-Sand manufacturers and cities in the Mekong Delta (km)

M-Sand manufacturing companies	Distance (km)
Phuoc Hoa Fico Joint Stock Company	114
Hoa An 1 Stone Company Limited	135
Thanh Tam Joint Stock Company	121
Hung Vuong Construction Co., ltd. Binh Phuoc branch	101
Hung Vuong Construction Co., ltd. Dong Nai branch	102
An Giang stone mining single-member limited liability company	73
Kien Giang Construction Materials Production Joint Stock Company	86

Source: Alluvium estimate from VIBM (2023)

Construction material demand in each of the 13 provinces and HCMC factors into aggregate transportation costs. The calculation for transport costs relies on averages calculated from the distances between cities and manufacturing locations and it is assumed that the yearly demand for aggregates is split between the cities based on their projected population growth.

A major challenge in conducting this analysis is estimating the demand for construction materials for each major urban area in the VMD. Beyond population growth, factors such as the pace of urbanization and city development play a crucial role in shaping the demand for concrete aggregates. These factors influence the types of buildings constructed and the scale of infrastructure projects like highways, bridges, and roads. Development guidelines from the Viet Nam government focusing on the Mekong Deltas region from 2021 to 2030 indicates that cities such as Can Tho, My Tho, Tan An, Long Xuyen, Rach Gia, Ca Mau, and Soc Trang have different development priorities that are tailored to their geographical and economic strengths such as administr*ative, trading, industrial, and tourism centres within the region.*[28] *The total costs from transporting river sand are compared against the total cost of transporting M-Sand to estimate the marginal difference in transporting M-Sand. A 90% buffer is also added on top of this estimate to factor in the uncertainty in the data.*

Table 8. Logistics input data

Parameter	Unit	L	M	H
Total cost for transporting M-Sand	USD per tonne	2.92	6.25	7.08
Total cost for transporting River sand	USD per tonne	1.28	3.85	6.41
Marginal costs for transporting M-Sand (cost for transporting M-Sand less cost for transporting River sand)	USD per tonne	0.67	1.63	2.40
90% cost buffer	USD per tonne	0.61	1.47	2.16
Modelled marginal costs for transporting M-Sand	USD per tonne	1.28	3.11	4.57

Source: Transport cost data was taken from a variety of different sources including RECERD (2022),[29] *a web search of river sand transport costs reported by Viet Nam state media.*

28 Decision No. 287/QD-TTg dated Feb 28 2022 for approval for planning for development of the Mekong delta region for the 2021 – 2030 period with vision towards 2050.

29 RECERD. (2022). Value Chain Analysis of Sand in the Vietnamese Mekong Delta.


© WWF-Viet Nam

3. FINDINGS

This section presents the findings of the CBA. Within a CBA, there are two key decision rules that are used by decision-makers and investors:

- **Net present value (NPV).** This is the value of the discounted benefits less the discounted costs for the full period of the analysis. A project or policy should have positive NPV to demonstrate economic viability.
- **The benefit-cost ratio (BCR).** This is the ratios of the discounted benefits over costs for the full period of the analysis. A project or policy should have a BCR greater than 1 to be viable. BCR's are also useful when comparing different options of different sizes (highest BCR is superior).

Because there is significant variability in the input data used in the quantitative CBA, we have undertaken significant sensitivity analysis (see Section 1.1 for method). The results below also show the range of final estimates for the key economic data – P10 (the 10th percentile means only 10% of all estimates fall below this figure); the P50 (the 50th percentile means 50% of all estimates fall below this figure) and the P90 (the 90th percentile means 90% of all estimates fall below this figure).

3.1. RESULTS

The results from the cost-benefit analysis are illustrated in Figure 7 and presented in Table 9. Over 20-year evaluation period, the CBA reports a modest benefit-cost ratio (BCR) of 1.27, ranging from 0.94 to 1.60. The estimated NPV is USD 0.32 B, ranging from USD -0.94 B to USD 1.60 B. The figure also shows that there is greater variation in the net present costs relative to the variation in the net present benefits. Transitioning to alternative aggregates as a replacement for river sand may be an economically viable initiative, but the variance in the results also suggest that the costs of this transition may outweigh the benefits.

Given the level of uncertainty in the BCR illustrated as part of the sensitivity analysis, it suggests that additional financial and/or legislative tools such as subsidies or taxes may be needed to facilitate and incentivise the transition to alternative aggregates. This is discussed further in Section 3.5.

Figure 7. NPB, NPC, and NPV

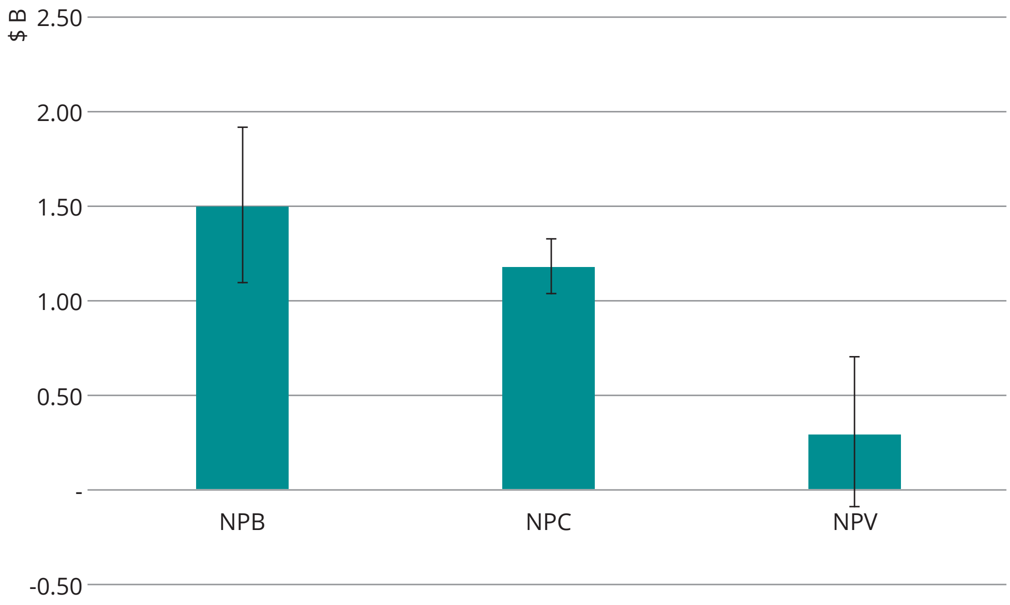


Table 9. CBA results

Parameter	Unit	P10	P50	P90
Net Present Value (NPV)	B USD	-0.08	0.32	0.70
Benefit-Cost Ratio	ratio	0.94	1.27	1.60

KEY POINTS

The CBA results (NPV and BCR) indicate that under most modelled scenarios assessed, the manufacture and use of manufactured aggregates is economically feasible.

Because there are several benefits of using manufactured aggregates that have not been included in this quantitative CBA (see Section 2.2), the estimated benefits are conservative, and the net benefits shown by the NPV and BCR are understated.

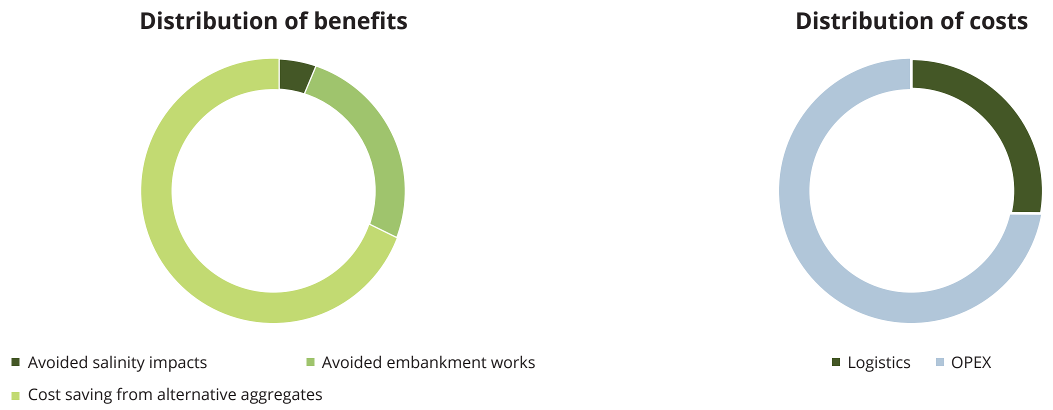
3.2. DISTRIBUTIONAL ANALYSIS

It is also useful to assess how the benefits and costs of manufactured aggregates are likely to be distributed across different impacts (e.g. cost savings to aggregate users compared to avoided salinity costs). Figure 8 illustrates the proportion of costs and benefits that are attributable to the CBA.

The cost savings to construction sector are approximately 64% of the total benefits, this is followed by the avoided costs of riverbank stabilisation infrastructure which is 30% of the benefits, and the avoided losses in agricultural productivity are valued at 6%.

Despite the significant capital outlay in the early years of the project. The bulk of the costs are from the operations of the facility (74%) and the costs for transport and logistics (26%).

Figure 8. Distribution of quantified benefits and costs

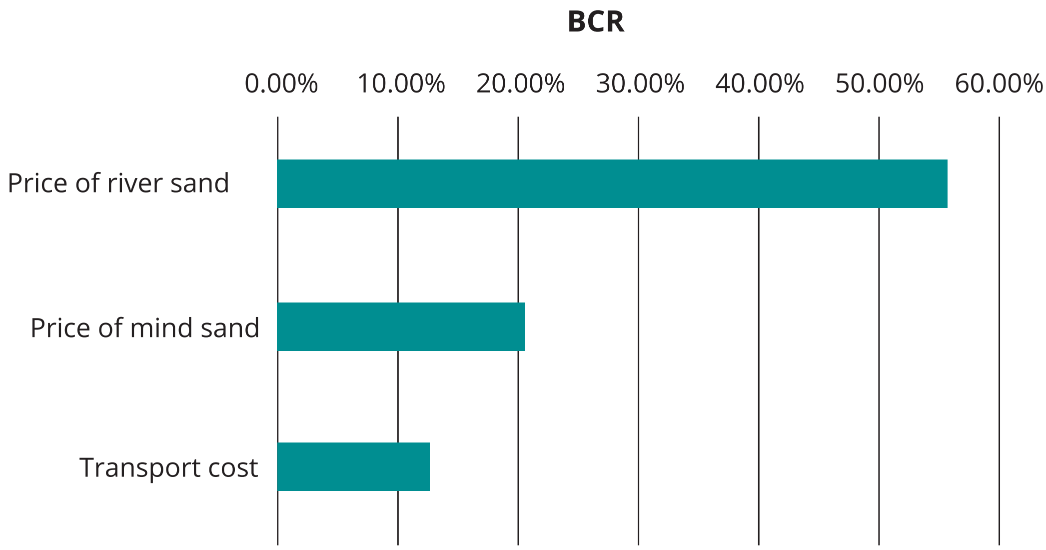


Note: CAPEX does not appear on the distribution of costs figure as it constitutes less than 1% of the total costs.

3.3. SENSITIVITY ANALYSIS

Monte Carlo simulations are used to simulate 10,000 different outcomes based on the variation in the input parameters. Figure 9 shows the parameters that contribute the most to the variance in the CBA results (cumulatively greater than 70% of the total variation). The input variables that contribute the most to the variation in the BCR are the price of river sand, the price of mine sand, and the transport costs. This is to be expected as the cost savings from the alternative aggregates drive most of the benefits.

Figure 9. Input parameter contribution to variance.



3.4. LIMITATIONS AND RECOMMENDATIONS

In this section certain limitations to our analysis are considered.

QUALITY OF DATA

Throughout this study, the limitations on the availability and quality of data are highlighted. Improvements in data will result in a more robust analysis and a better information base for decision-makers and investors. Section 3.3 of this report highlights the key types of data that impact the most on the findings of the economic analysis, and there, key opportunities to improve information and data.

IMPACT OF ILLEGAL EXTRACTION

This study does not explicitly consider the impacts of illegal sand mining. Illegal dredging may take place to service domestic and foreign demand. Although Viet Nam banned export of sand and gravel in 2017,[30] there remains the possibility that illegally mined sand and gravel has been exported out of the country. Research by Yuen et al. (2024) estimates that the volume of illegally mined sand has declined over 2013 from 16.7 Mm3 per year to 15.5 Mm3 per year as the permitted rate of extraction has increased.

Regardless, it is unlikely that the availability of alternative aggregates will induce behaviour change for those companies involved in illegal extraction. There are additional logistical costs associated with sourcing alternative aggregates and this additional financial burden serves as a barrier for firms to participate in practice change. Further, this may have the effect of driving an increase in illegal gravel extraction if the sourcing of alternate aggregates is found to be uneconomical. However, if the Government of Viet Nam did increase efforts to reduce illegal extraction, it would impact on demand for legal aggregate extraction and potentially the demand for manufactured aggregates.

30 TuoiTreNews.VN. (2023). Sand mining in Vietnam's Mekong Delta sinks homes, livelihoods. Accessed at https://tuoitrenews.vn/news/society/20231122/sand-mining-in-vietnam-s-mekong-delta-sinks-homes-livelihoods/76882.html#:~:text=Vietnam%20banned%20exports%20of%20sand,to%20the%20WWF-led%20study.

GENERATION OF ALTERNATIVE AGGREGATES

As highlighted above, there were significant challenges in modelling the volume of alternative aggregates that could be generated. The analysis conducted in this report was only able to incorporate current rates of materials generation based on current information. Crucially, this omits the development of other factors that may increase the generation of alternative aggregates such as change in the relative price of extracted a manufactured aggregates over the long-term.

This is especially pertinent when considering recycled concrete as a substitute for river sand as that was deemed the next-best replacement compared to M-Sand. VIBM (2023) suggests that creating well-defined technical instructions on incorporating recycled building materials into mortar and concrete mixes can encourage the growth of recycled concrete.

CHANGES IN FARM-LEVEL PRODUCTIVITY

While the potential increase in salinity poses a significant threat to rice production, it's important to acknowledge that this study doesn't account for the ongoing development and proliferation of salinity-resistant rice varieties that may mitigate risks to production. These varieties are specifically designed to be more durable under worsening conditions, potentially mitigating the projected loss of productivity under both the base case and the alternate scenario. For instance, a rapid review has identified the HATRI 200 rice variety as exhibiting higher salt tolerance and maintaining yield stability compared to other improved rice strains.[31] However, it's crucial to note that a comprehensive analysis of these new varieties and their potential impact on future rice production falls outside the scope of this project.

Additionally, farmers may adapt to higher salinity and convert their practices to shrimp farming instead (or hybrid rice and shrimp production). An article written by Bosquet and Turk (2022) in World Bank Blogs summarising one of the Bank's recent projects finds that farmers that allow their farms to be inundated during the wet seasons for aquaculture can achieve much higher income instead of farming rice alone. The decomposition of shrimps during the dry season can make soils more fertile during the dryer seasons, increasing rice productivity.[32] Valuation of this type of adaptation strategy is out of scope for this project and will require more location-specific data.

BENEFITS OF FLOOD MITIGATION STRATEGIES

While seasonal flooding of the Mekong River can bring some benefits to communities in the region, excessive inundation carries additional costs. This analysis overlooks a vital aspect: the potential impact of hard (e.g., concrete dikes) and nature-based (e.g., mangroves) infrastructure to mitigate erosion and provide salinity protection. Such infrastructure could significantly decrease the erosion benefits attributed to reducing sand mining, as the cost of mitigating impacts using nature-based solutions can sometimes be lower. Moreover, by fortifying coastal areas against erosion and saline intrusion, these strategies not only safeguard infrastructure and ecosystems but also help to keep residential areas in coastal communities more resilient, resulting in avoided relocation costs.

A more comprehensive approach should incorporate exploring cost-effective adaptation measures alongside finding alternative construction materials, thereby mitigating the need for costly relocations, and fostering sustainable development in vulnerable regions.

31 Vietnam News Agency. (2023). New salt tolerant rice variety to bolster Mekong Delta's response to climate change. https://en.vietnamplus.vn/new-salt-tolerant-rice-variety-to-bolster-mekong-deltas-response-to-climate-change/248775.vnp#:~:text=It%20is%20capable%20of%20tolerating,rice%20varieties%20in%20the%20delta.

32 World Bank Group. (2022). World Bank Blogs. How is Vietnam's Mekong Delta adapting to a changing climate?

3.5. POLICY OPTIONS

There are several policy options that could be considered by the Government of Viet Nam to reduce the risks and cost associated with aggregate extraction and to incentivise greater use of manufactured aggregates. These are briefly outlined below.

A TAX TO REFLECT NEGATIVE IMPACTS OF AGGREGATE EXTRACTION

A review of market-based policy instruments conducted by Hübler and Pothen (2021) suggests that an optimal tax structure would be to impose a **Pigouvian tax.**[33] This type of a tax internalises the social costs (environmental and social) to reflect the true cost of sand mining.

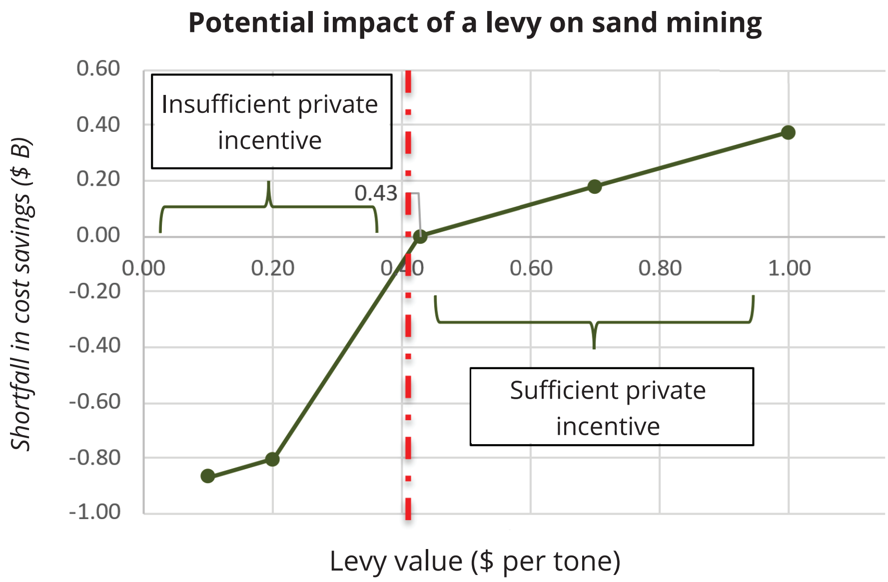
Unfortunately, since sand mining can impact areas across borders, implementing this solution is complex. Different countries regulating sand mining independently can simply push the problem elsewhere. Therefore, the approach recommended by Hübler and Pothen (2021) is an international agreement with a consistent tax rate applied across all sand mining countries. This would ensure everyone involved shares the responsibility for the environmental damage.

However, this approach will still require significant international coordination to determine and implement an appropriate tax rate. A more achievable approach may be to only impose taxes on companies within Viet Nam.

LEVY ON RIVER SAND MINING

Most of the benefits of adopting alternative aggregates are estimated to accrue to the construction industry. The benefit from the construction industry adopting alternative aggregates is worth roughly 70% of the total costs of this alternative. This means that there is currently insufficient commercial incentive for the construction industry in Viet Nam to move away from using river sand. Additional policy instruments may be required to encourage behaviour change.

Figure 10. Impact of a hypothetical levy on sand mining



33 Hübler, M., & Pothen, F. (2021). Can smart policies solve the sand mining problem? Plos one, 16(4), e0248882.

One example of this would be the imposition of a levy on sand mining companies which will have the effect of increasing sand prices. This will widen the gap between the price and river sand and the price of alternative aggregates. This is illustrated in Figure 10.

The diagram shows the how the difference between the private benefits of sand mining less the total costs of adopting alternative aggregates change as a levy on sand mining increases. An increase in the levy value will make alternative aggregates relatively more attractive relative to river sand.

Based on the current data, it is estimated that a levy value of USD 0.41 per tonne of sand mining would be required to ensure users of sand aggregates are indifferent between extracted and manufactured aggregates (i.e. the cost to end users is the same). Levy values to the left of this are insufficient to incentivise behaviour change, as there is still a shortfall in the cost savings. Levy values after this point may be sufficient to drive behaviour change as it is now economical for private actors to switch to M-Sand and recycled concrete materials.

A simplifying assumption made in this study is that the price of M-Sand and recycled concrete aggregate is the same regardless of location. There may be several reasons for the variability in prices across different locations such as quality, productive efficiency, transport costs etc. As such, it can be challenging to impose a uniform levy value across these different prices as the demand response may vary significantly.

Another option is to impose a proportional levy where the amount paid varies in proportion to the price of the product. There are different implications to whether this levy is imposed at the mine site or at the retail level. A levy imposed on the mine means that the burden of the levy falls directly on the sand mining companies involved in extraction and they are responsible for paying the levy before the sand is sold or distributed. This burden may be passed on in part or wholly to the construction company down the value chain, resulting in higher wholesale prices. A levy at the retail level means that the burden is born by the consumers (construction industry) and may offer the construction industry more transparency about the levy that they are directly paying. Determining the appropriate tax to charge will require additional research.

The potential implications of imposing a proportional levy at different points in the supply chain are presented in Table 10. Imposing a hypothetical 10% levy at the mine generates levy revenue of USD 6,000. In contrast, the same levy imposed at the retail level leads to a revenue of USD 12,000.

Table 10. Variation in levy revenue for Concrete Sand type 2 in Dong Thap

Location	Unit price (USD per tonne)	Unit price after a hypothetical 10% levy (USD per tonne)	Volume (tonnes)	Levy revenue (USD)
Mine	6.23	6.85	10,000	6,228
Retail	12.19	13.40	10,000	12,186

Source: Prices at the mine site are from Dong Thap BMC (2024) and prices for sand at the retail store are obtained from Truong Thinh Phat Construction Materials (2024).[34,35]

34 Dong Thap Building and Materials Construction. (2024). Materials prices. Accessed at https://dongthapbmc.vn/View.aspx?wp=4514 A15

35 Truong Thinh Phat Construction Materials. (2024). Prices of filling and construction sand in Dong Thap. Accessed at https://vlxdtruongthinhphat.vn/gia-cat-san-lap-cat-xay-dung-moi-nhat-hom-nay-tai-dong-thap/

PERMITS AND BUILDING CODES

In the medium term, it's crucial to address any regulatory barriers hindering the widespread adoption of M-Sand. Streamlining environmental permits and approvals for M-Sand plants can expedite the establishment of production facilities. Furthermore, incentivizing collaboration between government agencies, research institutions, and industry stakeholders can facilitate knowledge-sharing and technology transfer, leading to innovations in M-Sand production processes. This will have the effect of increasing uptake of alternative aggregates.

Moreover, integrating recycled concrete aggregates into building codes and procurement policies can create a steady market demand, driving investment in recycling technologies and processes. Additionally, public awareness campaigns highlighting the environmental and economic benefits of using recycled materials in construction can foster a culture of sustainability within the industry and among consumers. The building industry will need to be engaged in the process of updating the relevant codes and policies to overcome any perceived risks of adopting recycled concrete aggregates in building construction.

FINANCIAL INCENTIVES TO INCREASE SUPPLY OF RECYCLED CONCRETE AGGREGATES

Offering tax credits or grants for companies investing in recycling infrastructure, such as crushers and sorting facilities, can promote the utilization of recycled concrete aggregates in new construction projects. Other complimentary measures may include introducing landfill levies or disposal taxes to increase the supply of concrete waste. Following this, government investments into crushing and sorting facilities dedicated to concrete and demolition waste recycling can increase the availability of high-quality recycled aggregates. This will have the effect of increasing the supply.

While subsidies can also be a powerful tool to incentivise the use of alternative aggregates, its effectiveness can vary based on policy design. For example, employing a subsidy that increases with the volume can encourage greater adoption of alternative aggregates compared to a flat rate subsidy. However, subsidies can be costly to implement.

REGULATION AND ENFORCEMENT

Other options available would be to increase the regulatory standards and enforcement on the extraction of aggregates. This could include a range of initiatives including:

- Bans on extraction in highly sensitive environmental zones.
- Greater licensing and controls on extraction practices to reduce risks of extraction.
- Greater enforcement on illegal extraction.
- Changes to the allocation process for extraction of aggregates (potentially including access fees and/or competitive tenders to access the resource).
- Amending Government of Viet Nam procurement policies for use of aggregates to better reflect the risks, costs, and benefits of more sustainable practices, and to inventive the production of manufactured aggregates.

All these initiatives would increase the relative cost of extraction of aggregates compared to manufactured aggregates and would change the commercial incentives towards higher production and use of manufactured aggregates. The policy options canvassed in this section are not mutually exclusive and can work well when combined with each other, creating an enabling environment for the long-term transition away from river sand to alternative aggregates.

3.6. NEXT STEPS

Suggested next steps for this project include:

- Presentation of results and recommendations to the relevant stakeholders within the Government of Viet Nam to continue the policy dialogue on improved management, production, and use of aggregates.
- Undertake additional analysis to address the limitation outlined in Section 3.4 of this report.
- Commence a program of work to identify, scope and evaluate potential policy options to better manage the extraction and use of aggregates, including options to incentive manufactured aggregates and that reduce broad environmental and social costs on the community.

Working to sustain the natural world for the benefit of people and wildlife.

together possible™ vietnam.panda.org

For contact details and further information, please visit **vietnam.panda.org**