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Research Article

Dewatering process for reuse of seabed dredging material and time and cost optimization of the process by value engineering method

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ABSTRACT

The decrease in resources in the world has led people to produce new solutions for the more efficient use of resources and to use various management techniques. One of the techniques used is Value Engineering. Value Engineering strives to increase the value of structures by optimally organizing each component that makes up the structure. Increasing the value of a structure is possible by eliminating all the unnecessary costs in line with specific criteria and by providing the optimal solution between the owner, the user, and the contractor's objectives, that is, the duration, cost, and quality. This study includes the changes the Value Engineering team made to increase the value of the materials extracted from the submarine in a Container Port Terminal project without harming the environment and making them reusable. While expanding the project value, it also aimed to reduce the project duration and cost by considering the sustainability criteria. The original project was to create a clay pool while dewatering, separating the material, filling the loose sand into the reclamation area, and removing the sludge material by sea. With the recommendation of the value engineering team, the dewatering process was transformed into a method of directly pressing the dredged loose sand into the breeding area, filtering the material with geotextile tubes, and removing the material by loading it on the pontoons. With this change in the project, 42% savings were obtained from the cost and 21% from the project duration.

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1. INTRODUCTION

The perception that the concept of value creates in most people is the price, which is the monetary equivalent of the product. However, value is not a concept that can only be measured by cost and price. The highest value is the value that can safely perform the desired functions at the desired time and place and meet the basic quality requirement with the minimum possible total cost. The true value of a product is only revealed by comparing its quality, cost, or other characteristics with another product that performs the same functions [1]. Value, used in many different ways in many fields, such as philosophy, sociology, and mathematics, has also found a place in engineering. “Value Engineering (VE)” can be defined as a systematic approach to improving projects, processes, services, products, and organizations [2]. According to a different definition of VE, it is by customer requests, functions determined by the value engineering team through in-depth analyses of products and business processes, eliminating unnecessary ones from the process, and concentrating on the functions of utmost importance via the criteria determined by the value engineering team and customers; additionally, using a variety of idea generation techniques, carrying out the work in the form of choosing and implementing the least expensive among the alternatives that can solve the problem in its entirety.

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Maritime transportation has been essential to the sustainability of the countries' economies worldwide for centuries. With the spread of marine transport, there has been a significant daily increase in ship sizes and maritime traffic. This requires an increase in the size of ports and other marine structures. While building a larger navigational structure, dredging and removing the materials under the sea is necessary. Although most of these materials dredged from the seabed are wanted to be disposed of due to economic, logistical, legal, or environmental factors, it is possible to consider them a vital resource.

The widespread use of maritime transportation in trade makes ports the center of a country's economy [3]. The spread of marine transportation causes an increase in ship traffic and ship sizes. This situation reveals the necessity of dredging in port basins, transportation channels, and maneuvering areas. Dredging is essential for maintaining and developing ports and waterways for maritime transport, reclamation, and flood control [4]. As a result of dredging the channels, large amounts of dredging material are released. While most of this material is currently wanted to be disposed of for reasons related to the economy, logistics, law, or the environment, it can be viewed as a valuable resource. Some areas of use for this material have been defined in the literature. These areas of service are classified into three main categories.

- Engineering Applications: Coastal protection, flood control, coastal embankment, etc.
- Environmental Development Practices: Coastal embankment, creation and development of habitat, conservation of material resources, aquaculture and recreation, use as an agricultural product, etc.
- Manufacturing or Agricultural Products: Concrete material, brick, agricultural soil, etc. [5].

In the study conducted by Karadoğan et al. [6], it is shown that the materials obtained from the seabed dredging activities carried out in Türkiye can be used as filling materials on highways. In their study, Özer Erdoğan and Başar investigated the recovery of seabed dredging material, coal fly ash, and waste-cast sand as light aggregate [7]. There are studies in which the solidification and removal of the seabed dredging material by the dewatering method are applied, and the results are evaluated from various opinions [8-12]. In his study, McCafferty conducted a cost-benefit analysis of the dewatering process using geotextile tubes [13]. In a study by Pu et al. [14], they proposed an integrated method for rapid dewatering and solidification of dredged contaminated deposits with high water content. Noe and Kim proposed the sustainable and beneficial use of dredged materials in the Yangon River in Myanmar [15]. Karadoğan et al. [16] conducted a study on the dewatering of mine wastes with the help of geotextile tubes.

Value engineering has been applied to various construction projects for many purposes, such as increasing value, improving quality, shortening time, reducing cost, increasing project efficiency, and ensuring sustainability [17-22]. Value engineering has also been used to increase the value of marine structures for various purposes. Karkee et al. [23]'s study focused on different design concepts defined and evaluated through interactive collaboration between structural and geotechnical engineering disciplines before selecting design solutions that are ultimately considered for constructing a ferry terminal. Caspe et al. [24] conducted a study in which they benefited from value engineering in the environmental planning project of the Massachusetts Water Resources Authority for the MetroWest water supply tunnel.

This research delves into the application of Value Engineering within a Container Port Terminal project. Specifically, it examines the changes the Value Engineering team implemented to enhance the value of materials extracted from the sea. The primary aim of these changes is to streamline the project, reducing both time and costs. Notably, the modifications are designed to ensure the environmentally safe removal of these materials. The Container Port Terminal project serves as a practical example where the principles of Value Engineering are employed to optimize processes and resource utilization.

2. MATERIALS AND METHODS

2.1. Value Engineering Method

Value engineering seeks to avoid unnecessary costs when creating any product by examining its functions, designing it, creating a production process, organizing and managing the project, and eliminating components that are neither technically necessary nor desired by the customer, which drives up costs. It is a technique that aims to obtain the most valuable solution by analyzing the designs, processes, and specifications that can be obtained at the lowest cost in a way that provides the optimum benefit for the customer, removing the functions that are not needed from the process, as well as adding the necessary ones to the process if necessary [25].

The following is a list of the goals of value engineering, which refers to all of the research done by a multidisciplinary/stakeholder team made up of individuals not on the design team during the project's concept and design phases [26]:

- Providing the necessary functions safely, reliably, efficiently, and at the lowest cost.
- Increasing the value of the project.
- Reducing project completion time by using time effectively.
- Ensuring that the structure has a longer life.
- Eliminate unnecessary costs.
- To use existing materials, human resources, and money effectively and efficiently.
- Improve the quality of the project.
- Ensuring that the structure is more secure.
- Minimizing or even eliminating the mistakes and deficiencies in the project's drawing.
- By analyzing the project processes, removing the functions that do not contain value for the customer from the process, determining the necessary functions, and adding them to the process [27].

- Revealing staff skills with teamwork, creativity, adaptation, and psychological techniques.
- Apart from these, to produce value-based solutions to any problem encountered by using various creativity techniques.

To achieve these goals in Value Engineering, the processes are carried out in a certain systematic way. It is clear which techniques will be applied and the order in which they will be used. All operations are carried out in an application system called "Job Plan."

The concept of "value" expressed in value engineering can be expressed with the following formulas [28]:

Value=Merit/Cost (1)

Value=Customer Satisfaction/Cost (2)

Value=(Initial Impact of User+Benefit from Goods)
(Initial Cost+Subsequent Pricing) (3)

Value=Functionality/Cost (4)

Value=Benefit (Function)/Cost (5)

In Value Engineering, the problem must first be clearly defined. Once the problem is identified, a Value Engineering Team is created. If necessary, consultants can also be used, depending on the size of the problem. This team decides what criteria they should consider when solving the problem. In other words, each stakeholder specifies their expectations of the solution. Then, using various methods of generating ideas, it is tried to produce as many alternative solutions as possible in a way that can meet these criteria. These proposed solutions are evaluated in detail regarding their advantages, disadvantages, technical feasibility, and applicability. These evaluations are based on "value" through the abovementioned formulas. As a result, the most valuable alternative ideas that can be a solution are selected and implemented.

2.2. Dewatering and Reuse of Seabed Dredging Material

There are variations in needs and capacity increases due to the growing global population and globalization. Like in every other profession, transportation is one area where these shifting needs are evident. Every day, not only land transportation but also sea transportation evolves and expands. Maritime transportation is the method of moving vast amounts of semi-finished, finished, and raw commodities. In addition to freight transportation, it is also used in passenger transportation, albeit limited. The sea route is preferred when speed is not a factor because it can deliver significant quantities of goods over great distances and has a high degree of reliability while being slow [29]. This increase in the reasons for preference causes an increase in both the size and number of ships. As a result, all these needs also affect marine structures, and building systems large enough to meet the requirements is necessary. Large marine systems require dredging the sea bottoms and excavating and landing the materials there.

In addition, increasing urbanization and industrial activities worldwide bring many environmental problems. One of the most critical problems is the pollution caused by waste sludge with high water content. To solve the pollution of seas and streams, waste sludge is extracted by bottom dredging. Uncontrolled discharge of dredging sludge with high water content obtained due to the dredging activity in the oceans is the most common. It has been reported that this situation harms the marine ecosystem [30]. In Türkiye, bottom sludge has been dredged to clean seas and streams in recent years, and the materials with high water content obtained are stored in predetermined areas or discharged back to the sea [31]. It is of great importance that dredging sludge and waste sludge are dewatered for transportation, storage, and use in functional areas after extraction [32-34]. It will contribute positively to the country's economy and environmental health by applying dewatering effectively quickly and minimizing the harmful chemicals in its content.

The use of geosynthetic and polyacrylamide in the dewatering of waste materials with high water content is seen by researchers as an effective and economical option [35-37]. Geotextile tubes are tubular elements formed by assembling and sewing geotextile rolls and have the strength to hold relatively large amounts of water-saturated material. Geotextile tubes are porous, and when filled with a water-saturated material or slurry, the solid part is retained, and the water is filtered out of the pores of the geotextile, forming the tube [38].

Dewatering seabed dredging material is critical for environmental preservation and sustainability. It is essential to carefully consider both the application of the method and the subsequent evaluation of the materials obtained. In addition to all these, of course, the method to be chosen should also be economical, provided that it meets specific criteria. This study includes the changes the Value Engineering team made to increase the value of the materials extracted from the submarine in a Container Port Terminal project without harming the environment and making them reusable. By considering sustainability principles and ensuring that the activities to be carried out do not negatively impact the environment, the goal is to increase the project value while reducing its duration and cost.

2.3. Time And Cost Optimization of Dewatering Process in Container Port Terminal Project Using Value Engineering Method

In this study, the value engineering studies for the time and cost optimization of the Yarımca Container Terminal Project, which was built in the Gulf of Izmit, and the dewatering project of the seabed dredging material were analyzed, and Kayabaşı Aksu [39] explained this study in detail in her master's thesis.

The project was built on an old porcelain factory site, 20 km from Izmit and 80 km from Istanbul. In addition, the project is adjacent to Tüpraş, Türkiye's largest refinery. The total construction area is 504,883 m^2 and consists of 212,718 m^2 of land, 257,165 m^2 of sea (to be rehabilitated), and 35,000 m^2 of previously rehabilitated areas.

Project: Separation of silt for re-filling the material dredged from the sea.

Original Idea: Creating a clay pond, separating the material, filling the loose sand into the reclamation area, and removing the sludge material by sea.

Value Engineering Recommendation: Pressing the dredged loose sand directly into the breeding area, filtering the material with geotextile tubes, and removing the material by loading it on the pontoons.

2.3.1. Methodology

In project management, the anticipated and forecasted durations of activities often experience extensions, mainly when dealing with critical path activities. Such extensions can subsequently impact the overall project completion time. Beyond duration challenges, there are instances where the allocated budget for specific activities proves inadequate for their successful execution. To address these issues and ensure both timeline adherence and budgetary compliance, the application of the value engineering method emerges as a highly suitable solution. This approach allows for strategic modifications to the project to prevent delays and maintain financial constraints within the defined budget limits.

One of the essential activities to be carried out in the Yarımca Container Terminal Project, which is being built in Izmit Bay, is the dredging and deepening the seabed to increase the port capacity. Along with the issue of where and how the material obtained from dredging the seabed will be utilized, it is also essential to determine how long and how costly this process will be carried out. In this project, time and cost plans were made for each activity before the construction started and then the construction started.

In the original project prepared for the separation of the silt to use the material dredged from the sea in filling again, there was the idea of "creating a clay pool, separating the material, filling the loose sand into the breeding area, and removing the sludge material by sea." This idea made the time plan for the container port terminal project. It was observed that the initially anticipated budget and the originally scheduled time for silt separation had been exceeded one month after this method began to be implemented to solve the silt separation problem. It has been established that the silt separation activity is one of the crucial tasks in the container port terminal project, so extending its duration will also lengthen the project's overall duration. When there was a need to implement a different method to reduce the project's cost and shorten the time, a value engineering team was formed, and this team started to produce new ideas to achieve the specified goals. Among these ideas, "Pressing the dredged loose sand directly into the breeding area, filtering the material with geotextile tubes, loading the barges and removing the material" was chosen as the most appropriate method and decided to be applied.

In this project, when it was foreseen that the total project completion time and the total budget would be exceeded one month after the start of construction, it was decided to conduct a value engineering study for the activity "separation of silt in the dredged material from the sea and reuse or removal of the material obtained" on the critical path. For this purpose, the first thing to be done to apply the value engineering method is to decide which professional group should work together to realize the relevant activity. Value engineering can only be done with a team of stakeholders who can find the most optimum solution according to the applicable criteria to produce an appropriate solution to the relevant problem. In this study, for this purpose, a team of people from many professional groups who can make cost and time planning, who have developed themselves in the selection of materials that will not harm the environment and can be used in the solution of the problem, and who can produce ideas were formed and a time was set for this team to work. They were asked to produce as many ideas as possible. The aim expected from the solution is to produce ideas that can be used for recycling the materials extracted from the seabed without harming the environment as much as possible and to obtain a solution with a lower cost and duration than the original project. Among the suitable solution ideas produced during this period, with the help of various selection processes, the idea of "Pressing the dredged loose sand directly to the reclamation area, filtering the material with geotextile tubes, removing the material by loading it on pontoons" was determined as the most suitable solution and it was decided to implement it.

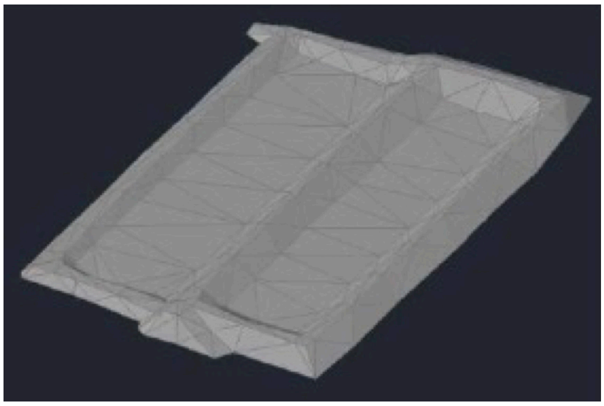

Figure 1. 3D view of the pools.

2.3.2. Analysis of the Original Design

By dredging the loose sand at a depth of 2-3 m on the surface of the sea area where the breeding area filling will be made;

- No soil improvement is needed in most of the reclamation areas.
- With the sand obtained from the dredge, the area created as the second area was filled, and thus, the dredged sand did not need to be removed and used in the filling by bringing materials from the outside.

Before the dredging activities started, two temporary pools were constructed on the Izmit side of the sea area. The purpose of making these pools is to take the silty material under the reclamation area before "Reclamation Area 2" is made and to minimize the possible settling of the reclamation area in the future. Thanks to these two pools, separating the dredged material and using the sand and gravel materials in the filling as recycling is planned.

The largest of the two pools to be created is 35,000 m^3, and the smallest has a capacity of 20,000 m^3 (Fig. 1).

Figure 2. Overview of application 1.

Before the construction of the small pool was completed, 12 pipes were placed at three different elevations to provide a connection between the two pools. The upper width of the area, which is 620 m in length, was manufactured as 7 meters. The total material dredged from the floor of this area was 35888 m^3. An overview of Application 1 can be seen in Figure 2.

It has been calculated that the material accumulated in the temporary pool was 6137 m^3 waste silt. Due to the mud consistency of the material, the material that could not be sent to the dump site was mixed with the excavation from another area in the project, and some of it was sent to the dump site. However, 138.95 tons of unquenched limestone were thrown into the material with high viscosity to reduce this rate and placed on hold. The leftover lime dried the material in the pool. It wasn't, however, sent to casting just yet. The channels for drying and resting the material were opened due to its high fluidity. The collected water was then released from the surface. After blending the slime silt that was still within with the reclamation area material again, it was made dense enough to be hauled by trucks using material gathered from nearby excavations and then transferred to the excavation. The embankment between the two pools was demolished, channels were opened in the pool, and the accumulated water was discharged. The delivery of the material, whose fluidity decreased with the effect of the season, took 132 days.

The materials, equipment, and manpower used in the dismantling stages of the temporary reclamation area are as follows (h: hour) (Table 1):

Table 1. Materials, equipment, and labor used in the dismantling of the temporary reclamation area

Source	Quantity	Type
Tipper truck	894,48 h	Machine
Hyundai 290 excavator	637,44 h	Machine
Volvo 290 excavator	497,60 h	Machine
Hidromek 370 excavator	554.00 h	Machine
Short-sleeved JCB	162,00 h	Machine
Long-sleeved JCB	150,00 h	Machine
Disposal on land	46418,63 m^3	Transporting
Operator	150,00 h	Employee
Hitachi excavator	22,00 h	Machine
CAT 330 excavator	105,04 h	Machine
CAT 96F loader	28,08 h	Machine

2.3.3. Cost Analysis of Original Design

The costs for separating the sludge material by creating a 55,000.00 m^3 clay pond and removing it by sea are given in Table 2. While calculating the total costs of the workers and machines in the tables, it is accepted that they work 8 hours a day, and subcontractor costs are given in lump sums.

The cost of transferring the separated loose sand to the reclamation area is given in Table 3.

The cost of pressing the sludge material into the clay pool with a pump, drying the pool with lime, and transporting it to the dumping site by sea is given in Table 4.

The total cost summary of Application 1 is given in Table 5.

2.4. Analysis of Value Engineering Proposal

The value engineering team proposed several changes to the original project to reduce the cost and duration of the project. It was decided that the suggestion of "pressing the dredged loose sand directly into the breeding area, filtering the material dredged under the sea with a geotextile tube, and removing it by loading it on the pontoons" was the most appropriate among these solutions. The silt within must be removed and returned to the seabed without endangering the environment for components like sand and gravel from the material taken from the seabed to be utilized once more

Table 2. The clay pool cost of Application 1

Resource name	Type	Quantity	Unit	Unit price ($/h)	Total price ($)
Plain worker	Workmanship	57	Day	2.8	1276.8
Foreman	Craft	19	Day	10,2	1550.4
Hitachi rental excavator	Machine	5,84	Day	44.54	2080,91
Hitachi rental excavator diesel	Machine	5,84	Day	33.13	1547,83
CAT 330 excavator rent and diesel	Machine	7.19	Day	118	6787,36
Dozer D7 rent	Machine	4,94	Day	28,35	1120,39
Dump truck rent	Machine	30	Day	23	5520
Filling of suitable material	Sub-contractor	39370,67	m^3	2	78741,34
Excavation of suitable material	Sub-contractor	39370,67	m^3	2.3	90552,54
CAT 533 cylinder rent and diesel	Machine	1	Day	56.6	452,80
Total					**193085,83**

Table 3. Cost of transferring loose sand to the reclamation area in Exercise 1

Resource name	Type	Quantity	Unit	Unit price ($)	Total price ($)
Master	Workmanship	389,24	Day	10.2/h	31761,98
Operator	Workmanship	778,48	Day	3.5/h	21797,44
Hidromek 370 excavator rental	Machine	170,95	Day	52/h	71115,20
Hidromek 370 excavator diesel	Machine	170,95	Day	69,61 /h	95198,64
CAT 330 excavator	Machine	104,36	Day	118 /h	98514,33
JCB loader 467 ZX depreciation	Machine	2.95	m^3	17 /m^3	50,08
JCB loader 467 ZX oil	Machine	2.95	Day	31,37 /h	739,23
Dozer-D6 rent	Machine	63.44	Day	28,35 /h	14387,19
Dozer-D6 oil	Machine	63.44	Day	42.80 /h	21720,35
Total					**355284,44**

in areas that require filling and in port development. Thus, while increasing the sea depth where the port will be built by removing material from the seabed, the material extracted from it will be used again in the areas where it is needed. The silt in the material extracted from the sea will be separated from other materials, poured back into the sea, and disposed of without harming the environment.

Figure 3 shows the preparations made so that the slurry material accumulated in the part indicated by the red line can be dewatered and thrown out. The parts shown with white arrows show the drilling work carried out.

To clean the sludge pool, the materials (toyo pump, 10'' and 6'' hose, trailer, mineral, polymer, and sludge tubes) required for the dewatering process recommended by the value engineering team were brought to the site. The sequence of operations of the dewatering method was as follows:

- Pulling the sludge from the pool with the toyo pump
- Transferring the sludge to the trailer with the help of 10'' and 6'' hoses
- Mixing sludge with minerals and polymers in trailers
- Transferring the mixture to geotextile tubes with 6'' hoses
- Filtration of water separated from the sludge precipitated in the tubes
- Removing the sludge from the site by opening the tubes

The materials brought to the site to clean the sludge pool were prepared for dewatering. As the first process step, the material was withdrawn from the pool at a flow rate of 350 m^3/h with the help of a 110 kW toyo pump crane. For the removed material to provide the desired decomposition, the content of the material must be 90% water and 10% solid (clay and silt). This ratio was obtained as a result of tests performed in the laboratory. To adjust this ratio during material pulling with the pump, the crane operator has a monitor showing the amount and ratio of material pulled. Thanks to this dredge, the operator has achieved the desired ratio by moving the pump up and down in the water. The material pulled in the desired proportions was transferred to the trailer with 10'' and 6'' hoses. Tests were performed in the laboratory to remove water from the sludge and allow the solid material to precipitate. As a result of these tests, two different materials were determined as minerals and polymers that provide optimum decomposition. The

Table 4. In Application 1, the cost of pressing the sludge material into the clay pool and transporting the lime to the marine dumping area

Resource name	Type	Quantity	Unit	Unit price ($)	Total price ($)
Dump truck rental	Machine	93,92	Day	23/h	17281,35
Hyundai 290 excavator rental	Machine	66.93	Day	37/h	19811,64
Volvo 290 excavator rental	Machine	52,25	Day	37/h	15465,41
Hidromek 370 excavator rental	Machine	58,17	Day	52/h	24198,72
JCB short-sleeve excavator depreciation	Machine	17,01	Day	20/h	2721,60
JCB long-sleeve excavator depreciation	Machine	15,75	Day	20/h	2520
Disposal on land	Machine	39370,67	m^3	11,14/m^3	438589,26
Operator	Workmanship	32.76	Day	3.5/h	917,28
Dump truck diesel	Machine	93,92	Day	7,35/h	5522,52
Hyundai 290 excavator diesel	Machine	66.93	Day	44.54/h	23848,93
Volvo 290 excavator diesel	Machine	52,25	Day	33,13/h	13847,81
Hidromek 370 excavator diesel	Machine	58,17	Day	69,61/h	32393,71
JCB short arm excavator diesel	Machine	17,01	Day	50,82/h	6915,59
JCB long-arm excavator diesel	Machine	15,75	Day	51.47/h	6485,22
Hitachi excavator rental	Machine	2,31	Day	44.54/h	823.1
Hitachi excavator diesel	Machine	2,31	Day	33,13/h	612,24
CAT 330 excavator rent and diesel	Machine	11,03	Day	118/h	10411,56
Mud pump	Machine	56	Day	36.12/h	16181,76
Quicklime	Machine	627,52	Day	59,10/h	37086,43
CAT 966F loader rent and diesel	Machine	2.95	Day	76.39/h	1801,83
Transportation to the marine dumping area	Transporting	28000	Hour	5,69/h	159320
Total					**836755,96**

Table 5. Total cost of application 1

	Cost ($)
Cost of the clay pond	193085,83
The cost of pressing the sludge material into the clay pool and transporting the lime to the marine dumping area	836755,96
Cost of transferring loose sand to the reclamation area	355284,44
Total	**1385126,23**

formation of flocculation in the material transferred to the trailer was constantly controlled, and the mineral ratio used accordingly was adjusted between 2 and 4 kg/ton DS (Solid Matter). In addition, 0.5 to 1 kg/ton of polymer was used.

A sample assembly was installed in the system to control the flocculation results instantly. This system consists of one transparent tube and two valves (Fig. 4). The valve under the transparent tube is opened to see the mixture coming from the trailer, and the material is taken into the transparent tube. If the desired flocculation is achieved, the solid material collapses to the bottom of the transparent tube in small lumps while the water decomposes on the collapsed solid. To see this separation again, the process can be repeated by emptying the tube from the valve on the transparent tube.

Geotextile sludge tubes coming to the site in rolls are rolled and laid to the places determined by the length of the supply hoses coming out of the trailer with manpower. When the material is pressed into the laid tubes, the tubes are tied with rope from the binding ears on the tube to the vaults until the tubes reach a certain height to prevent the tubes from tilting to the right and left while displacing and inflating. There are four filling chimneys on each sludge tube. These chimneys have a diameter of 0.3 m and a length of 1.0 m. The supply pipe is fixed to one of the filling chimneys with a suitable belt. The treated slurry was filled into the tube utilizing 6" supply hoses using these chimneys. From the moment the material is pressed into the tubes, the solid (clay, silt) settles at the bottom of the tube in the flocculated material, while the water remaining on the surface drains out of the sludge tubes designed to provide filtration. Drainage channels with a width of 60 cm and a depth of 50 cm were opened around the sludge tubes to prevent the drained water from dispersing into the field. The channels are surrounded by a safety strip so that the opened channels do not cause any accidents. With these channels, water discharge is controlled without dispersing to the site.

Figure 3. Reclamation area ground improvement – overview.

Figure 4. Flocculation instantaneous control.

Given that the volume of solids in the tubes rose once they reached a height of one meter, compaction was performed on the sludge tubes with a compactor to prevent the clogging of the pores where the sludge filtering took place and to ensure better water drainage. The filling and compaction process of the tubes was continued until the maximum height reached 2.10 m. When the height of the sludge tube reached the maximum level, the process of pressing material into the tubes was terminated, and the tubes were left to wait for 10 days for final filtration. During the final waiting period, samples were taken daily from the filling chimneys in the tubes and checked. When the samples taken at the end of 10 days were examined, it was seen that the material in the tubes was suitable for transportation. When the tubes became suitable for transportation, they were cut and opened, controlled with a snap blade. The removal of the resulting material from the site took place in 4 stages:

- Loading the material into the truck with an excavator
- Unloading into the loading pond by trucks
- Uploading from the upload pool to split dump barge
- Discharging by ship to the previously designated site

After the tubes were opened, 600 m^3 of material came out of each tube. The material coming out of the tubes was loaded into the trucks with the help of an excavator. The trucks unloaded the material into the loading pond. From here, it was loaded onto the split dump barge with a long boom excavator. Each sludge tube fills a split dump barge. When the loading of the split dump barges was completed, the ship went to the discharge site and discharged the material, and thus, the dewatered silt material was safely removed from the site.

Table 6. Cost of application 2

Resource name	Type	Quantity	Unit price	Total price ($)
Dump truck rental	Workmanship	98,08	23/h	18046,72
JCB short-sleeve excavator depreciation	Workmanship	49,04	20/h	7846.4
Hitachi Zaxis Long arm excavator	Machine	49,04	35,83/h	14056,83
Destruction at sea	Transporting	28000	5,69/h	159320
Geotextile subcontractor cost	Sub-contractor	1	550000/ls	550000
Operator	Workmanship	98,08	3.5/h	2746,24
Dump truck diesel	Machine	98,08	7,35/h	5767.1
JCB short arm excavator diesel	Machine	49,04	50,82/h	19937.7
Hitachi Zaxis Long arm excavator	Machine	49,04	49,36/h	19364,92
Mud pump	Machine	68,66	36.12/h	19838,84
Total				**816924,75**

Figure 5. Completed Yarımca container terminal project.

Since geotextile dewatering tubes are "disposable" materials, the remaining tube residues were disposed of according to local regulations after the processed sludge was transported in a way that would not pollute the environment.

2.4.1. Cost Analysis of Exercise 2

As a result of the change proposed by the value engineering team in the project, the cost of the application stages of the method of dewatering and separating the sludge material with geotextile tubes and removing the material by sea is given in Table 6 (ls: Lump Sum).

The completed version of the Yarımca Container Terminal Project can be seen in Figure 5.

3. RESULTS

The benefits/results obtained as a result of the applications in the projects proposed by the original and value engineering team are shown below:

The cost impact of:

- The total cost in Application 1 is 1,385,126.23 USD,
- The total cost of Application 2 is 816,924.75 USD,

The total cost difference between the two applications was calculated as 568,201.48 USD. Hence, 42% savings were made in terms of cost.

Time effect:

- In Application 1, creating a clay pool, separating the material, filling the loose sand into the reclamation area, and removing the sludge material by sea were calculated as a total of 451 working days.
- In Application 2, it was planned to press the dredged loose sand directly into the breeding area, filter it with geotextile material, load it on the pontoons, and remove the material for 359 days.

The time difference between the two applications was 92 days. 21% savings were made in terms of time.

Sustainability impact:

- With this application, the material dredged from the seabed was cleaned from silts and used in backfilling and other necessary construction activities at the port in the project.

4. CONCLUSION

Because shipping is one of the most significant ways to move vast quantities of semi-finished, finished, and raw goods, both the size and number of ships in use have grown, necessitating the construction of marine buildings that are big enough to satisfy demand. Dredging the seabed and excavating and landing materials are additional requirements for large marine buildings.

In this study, one of the stages of the Yarımca Container Terminal Project built in the Gulf of İzmit, the studies carried out to separate the silt for refilling the material dredged from the sea were examined. The value engineering studies carried out for the time and cost optimization of the dewatering project of the seabed dredging material were explained. During the port construction process, after the material is extracted from the sea, these materials must be separated and removed from the area for reuse without harming the environment. In this project, the idea was "creating a clay pool, separating the material, filling the loose sand into the reclamation area, and removing the sludge material by sea" during the project's design phase to separate the silt existing in the extracted materials. The time and budget planning of the project were also based on this idea. One month after the implementation of this idea, it was understood that the initially estimated budget and time limits were exceeded, and the total project duration was prolonged since the activity containing this idea was also critical. Therefore, in this process, a value engineering study has been carried out on the project, and the need to shorten the cost and duration has become indispensable.

As a result of their work, the value engineering team concluded that the idea of "pressing the dredged loose sand directly into the breeding area, filtering the material with geotextile tubes, and removing the material by loading it on the pontoons" is an appropriate method to both reduce the cost and shorten the time within the framework of sustainability principles without harming the environment. With this method, it was ensured that the elements such as sand and gravel in the material extracted from the seabed were separated from the silt to be used again in places where filling is needed and in port construction, and this silt was transported to the seabed again without harming the environment. Thus, while increasing the sea depth in the area where the port will be built by removing material from the seabed, the material extracted from the seabed was used again where it was needed. The silt extracted from the sea was separated from other materials, poured back into the sea, and disposed of without harming the environment.

Although not implemented in this project, silt material, which is subjected to dewatering by means of geotextile tubes in similar project applications, can be evaluated in the cosmetics sector according to its content by performing the necessary tests (silt can be used in the production of various cosmetic products, including creams, lotions, gels, make-up materials, and other).

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The authors declared that this study has received no financial support.

PEER-REVIEW

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REFERENCES

[1] Atabay, Ş. (2023). Value Engineering in construction projects. In Cengiz, M. S., & Ozkaya, U. (Eds.), *Küreselleşen Dünyada Mühendislik ve Mimarlık* (pp. 107–139). Duvar Yayınları.

[2] SAVE International. (2023). About the value methodology. https://www.value-eng.org/page/AboutVM

[3] European Environment Agency. (2023). *News: EU maritime transport*. https://www.eea.europa.eu/highlights/eu-maritime-transport-first-environmental

[4] International Association of Dredging Companies (IADC). (2023). The importance of dredging. https://www.iadc-dredging.com/subject/what-is-dredging/the-importance-of-dredging/

[5] Demirbaş, N. (2016). *Assessment and beneficial use of the material from seabed dredging operations* [Master's thesis, Istanbul Technical University].

[6] Karadoğan, Ü., Çevikbilen, G., & Teymür, B. (2020). Use of dredge materials as road embankment. *Uludağ Univ J Fac Eng, 25*(2), 1059–1070. [CrossRef]

[7] Özer Erdoğan, P. & Başar, H. M. (2019). Recycling of marine dredged materials, coal fly ash and waste foundry sand as lightweight aggregates. *J Fac Eng Archit Gazi Univ, 34*(3), 1377–1394.

[8] Karadoğan Ü., Korkut, S., Çevikbilen, G., Teymur, B., & Koyuncu, İ. (2021). Evaluation of beneficial of polyacrylamide use dewatering of dredged sludge obtained from Golden Horn. *Mar Georesour Geotechnol, 39*(8), 919–928. [CrossRef]

[9] Cao, B., Zhang, T., Zhang, W., & Wang, D. (2021). Enhanced technology based for sewage sludge deep dewatering: A critical review. *Water Res, 189*, 1–19. [CrossRef]

[10] Karadoğan, Ü., Çevikbilen, G., Korkut, S., Pasaoglu, M. E., & Teymur, B. (2022). Dewatering of Golden Horn sludge with geotextile tube and determination of optimum operating conditions: A novel approach. *Mar Georesour Geotechnol, 40*(7), 782–794. [CrossRef]

[11] Zhang, H., Sun, H. L., Liu, S. J., Chu, J., Shi, L., Geng, X. Y., Deng, Y., & Cai, Y. Q. (2023). Large-strain consolidation of sludge in multiple-drainage geotextile tubes. *J Geotech Geoenviron Eng, 149*(6), 04023037. [CrossRef]

[12] Li, C., Song, Z., Zhang, W., Li, L., Liao, G., & Wang, D. (2022). Impact of hydroxyl aluminum speciation on dewaterability and pollutants release of dredged sludge using polymeric aluminum chloride. *J Water Process Eng, 49*, 103051. [CrossRef]

[13] McCafferty, C. M. (2021). A cost-benefit analysis for geotextile tube dewatering with and without a spacer product [Doctoral Thesis, Drexel University].

[14] Pu, H., Mastoi, A. K., Chen, X., Song, D., Qiu, J., & Yang, P. (2021). An integrated method for the rapid dewatering and solidification/stabilization of dredged contaminated sediment with a high water content. *Front Environ Sci Eng, 15*, 1–12. [CrossRef]

[15] Noe, K. M., & Kim, K. (2020). Preliminary framework for sustainable beneficial use of dredged materials in Yangon River, Myanmar. *J Water Chem Technol, 42*, 514–521. [CrossRef]

[16] Karadoğan, Ü., Çevikbilen, G., Korkut, S., & Teymur, B. (2022). Dewatering of mine waste using geotextile tubes. *Min Metall Explor, 39*(6), 2477–2490. [CrossRef]

[17] Atabay, Ş. (2021). Value engineering for the selection of the filler material between shoring wall and the structure. *Tehnički vjesnik, 28*(6), 2164–2172. [CrossRef]

[18] Albarbary, M. M., Tahwia, A. M., & Elmasoudi, I. (2023). Integration between sustainability and value engineering in the production of eco-friendly concrete. *Sustainability, 15*(4), 3565. [CrossRef]

[19] Taher, A. H., & Elbeltagi, E. E. (2023). Integrating building information modeling with value engineering to facilitate the selection of building design alternatives considering sustainability. *Int J Constr Manag, 23*(11), 1886–1901. [CrossRef]

[20] Gunarathne, A. S., Zainudeen, N., Perera, C. S. R., & Perera, B. A. K. S. (2022). A framework of an integrated sustainability and value engineering concepts for construction projects. *Int J Constr Manag, 22*(11), 2178–2190. [CrossRef]

[21] Alsanabani, N. M., Al-Gahtani, K. S., Bin Mahmoud, A. A., & Aljadhai, S. I. (2023). Integrated methods for selecting construction foundation type based on using a value engineering principle. *Sustainability, 15*(11), 8547. [CrossRef]

[22] Atabay, Ş. (2023). Determination of exterior material in sustainable buildings by value engineering method according to LEED criteria. *J Sustain Constr Mater Technol, 8*(1), 1–11. [CrossRef]

[23] Karkee, M. B., Horvitz, G. E., Chamberlain, M. B., Gastineau, A. J., Bennett, A. K., & Mooney, T. (2022). Geotechnical and structural adaptations for the seismic design of a new ferry terminal in Washington. *Ports, 2022*, 848–858. [CrossRef]

[24] Caspe, H. P., Kim, A. Y., Bergen, L. J., & Araujo, J. R. (1994). *Environmental planning for the Massachusetts Water Resources Authority's MetroWest water supply tunnel*. In Tunnelling '94. Springer, Boston, MA. [CrossRef]

[25] Gupta, V. K. (2009). Flexible strategic framework for managing forces of continuity and change in value engineering processes: Study in Indian context. *Glob J Flex Syst Manag, 10*(4), 55–65. [CrossRef]

[26] U.S. Department of Transportation Federal Highway Administration. (2017, June 27). *The value engineering (VE) process and job plan*. https://www.fhwa.dot.gov/ve/veproc.cfm

[27] Kazanç, D. (2000). *Value engineering in construction* [Master's thesis, Istanbul Technical University].

[28] Fowler, T. C. (1990). *Value analysis design (Competitive manufacturing series)*. John Wiley & Sons, USA.

[29] Deniz, T. (2016). Türkiye'de ulaşım sektöründe yaşanan değişimler ve mevcut durum. *Doğu Coğrafya Derg, 21*(36), 135–156. [CrossRef]

[30] Sheehan, C., & Harrington, J. J. W. M. (2012). Management of dredge material in the Republic of Ireland - a review. *Waste Manag, 32*(5), 1031–1044. [CrossRef]

[31] Çevikbilen, G., Başar, H. M., Karadoğan, Ü., Teymur, B., Dağlı, S., & Tolun, L. (2020). Assessment of the use of dredged marine materials in sanitary landfills: A case study from the Marmara sea. *Waste Manag, 113*, 70–79. [CrossRef]

[32] Moo-Young, H. K., Gaffney, D. A., & Mo, X. (2002). Testing procedures to assess the viability of dewater-

ing with geotextile tubes. *Geotext Geomembr, 20*(5), 289–303. [CrossRef]

[33] Liao, K., & Bhatia, S. K. (2005). *Geotextile tube: Filtration performance of woven geotextiles under pressure*. Proceedings of NAGS 2005/GRI – 19 Cooperative Conference, Las Vegas, NV, USA.

[34] Lawson, C. R. (2008). Geotextile containment for hydraulic and environmental engineering. *Geosynth Int, 15*(6), 384–427. [CrossRef]

[35] Ratnayesuraj, C. R., & Bhatia, S. K. (2018). Testing and analytical modeling of two-dimensional geotextile tube dewatering process. *Geosynth Int, 25*(2), 132–149. [CrossRef]

[36] Müller, M., & Vidal, D. (2019). Comparison between open and closed system for dewatering with geotextile: Field and comparative study. *Int J Civ Environ Eng, 13*, 634–639.

[37] Aparicio Ardila, M. A., Souza, S. T. D., Silva, J. L. D., Valentin, C. A., & Dantas, A. D. B. (2020). Geotextile tube dewatering performance assessment: An experimental study of sludge dewatering generated at a water treatment plant. *Sustainability, 12*(19), 8129. [CrossRef]

[38] E Silva, R. A., Negri, R. G., & de Mattos Vidal, D. (2019). A new image-based technique for measuring pore size distribution of nonwoven geotextiles. *Geosynth Int, 26*(3), 261–272. [CrossRef]

[39] Kayabaşı Aksu C. (2019). *Research on value engineering with applications in marineconstruction* [Master's thesis, Yildiz Technical University].