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Simulation-Based Cost Evaluation of Maritime Transportation

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Abstract

In a globalized world, maritime transportation is a crucial component for both producers and consumers. In this sector, where 10 billion tons of freight are moved each year, both shippers and carriers grapple with financial obligations. The requirement for ship operators to perform precise cost calculations is growing daily to stay competitive and avoid financial difficulties because of high investment and operational costs. However, traditional costing methods, which are already in use, are believed to be unable to provide businesses with the precise information they require. Therefore, in this study, the cost structure of ship management is examined and the activity-based costing (ABC) method is used with the help of simulation. The data obtained from the ABC model created with simulation support were compared with the companies' current traditional costing methods. The results show that there is a difference in the calculations between the simulation-based ABC method and the traditional costing method. According to this study, the cost difference is approximately $7,000. Considering that the firm's annual total cost remains unchanged, it can be assumed that the costs for loadings other than the one under consideration are higher than expected.

Keywords: Simulation, ABC, Costing, Maritime transportation management

1. Introduction

In today's world, where global rivalry is increasing by the day, businesses must build a stringent and long-term financial management system to remain competitive. With the increase in competition, there is a greater requirement for precise cost structure evaluation [1]. A precise cost structure is an important factor that influences the entire company's management in all aspects [2]. Companies use a precise cost structure to establish prices and pinpoint areas where spending could be trimmed. Among all expenses, transportation expenditures play a significant role in the expenditure elements that comprise these cost structures.

Maritime transport is a key actor in supplying numerous needs, such as raw materials, products, and equipment, that enterprises in a global marketplace require. However, maritime transport takes its share from the strict financial management approach brought about by global competition. The expectations of cargo owners, who desire to transport their cargo in the most financially feasible manner, are forcing shipowners and/or ship operators (SOs) to implement a sustainable strategic financial management system. With the 80% volume of international freight transportation, the maritime transport service spectrum covers all sectors; thus, the effects of the financial management systems of shipowners and/or ship management companies could be felt by all sectors. Even with the global economy contracting owing to the pandemic, the volume of cargo transported by merchant vessels was estimated to be 11 billion tons in 2022 [3].

SOs confront various cost structures to perform their freight transportation. Two categories of maritime transportation expenses are examined. The first is the fixed costs that guarantee that the ship is ready for the next journey and the cargo, and the second is the variable costs, which change depending on the type of cargo being transported and the distance. On the other hand, fixed costs can be separated into two categories within themselves [4]. Capital costs include expenses such as building a ship, depreciation, and financial outlays. In addition to these costs, expenses for flagging, registries, insurance, staffing, and regulations

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could be categorized as fixed operational costs. The two fixed cost items mentioned above are the costs to keep the ship sailing. The owner of the ship must pay for these expenses even if it does not engage in transportation because otherwise, it will not be suitable for the next voyage and transportation. Variable costs, which vary on the basis of loading and distance, comprise the other cost category. Variable cost examples include fuel costs, canal tolls, and port fees. The age of the ship may impact all of these costs. As the ship continues to age, the cost of capital decreases. On a ship that is five years old, the capital cost is 47%; however, on a ship that is twenty years old, the cost just covers 11% of all expenses [5]. However, as a ship gets older, maintenance, repair, and operational costs, as well as costs associated with mandated changes to regulations, increase [6]. SOs focus on these adjustments as the most critical issues during the cost estimation stage. Investment and operational costs vary even at different ages of the same ship. It is becoming increasingly vital for SOs to perform accurate cost assessments for sustainable shipping due to changes in the global economy, cost variability [6], and a more competitive market.

As mentioned above, costing is a critical management tool [7]. For this reason, this study aims to improve shipping companies' financial capability to foresee [8] the financial challenges they will face in their freight transportation at an operational level. The improvement of financial capability and the development of several financial scenarios are expected to aid organizations in maintaining their competitiveness. It is also expected to be beneficial in the development of a sustainable economic model. In this study, the activity-based costing (ABC) model, which is commonly used in the service industry, particularly in manufacturing, is integrated with simulation to allow SOs to produce more accurate cost estimations. The research was conducted on a specific journey (from Tekirdağ Port to Bari Port) that transports bulk cargo to be a pioneer and an example of its utilization in ship management. Sparse, average, and intensive outcomes that can occur are achieved and evaluated through simulation. The generated findings were compared with traditional cost calculation results, which are the most frequently used cost calculation approach in ship management and other areas. The modeling findings employed in the study with the traditional costing method showed differences, as indicated by the comparison results. SOs are unable to compete effectively enough in the global marketplace because of these disparities.

2. Literature Review

Cost calculation is a critical issue for businesses in determining profitability. Increasing competitiveness because of the industrial revolution has compelled businesses to operate more prudently financially. According to the literature, various cost analyses have been conducted in all industrial and service industries. Despite this, there is less research in the maritime sector. However, these investigations discovered that they confined their cost estimations to certain cost elements. The majority of these studies fall under the category of maritime economies of scale. In other words, these are studies on the decline in cost items with an increase in service production. For instance, several corporations have explored the economic effectiveness of building bigger ships to lower the number of escalating expenditures per unit load [9]. It has also been stated that increasing the tonnage of ships, particularly bulk carriers and newly constructed ships, will cut unit prices [10]. Likewise, research has been conducted to reduce the unit price of container shipping with large-tonnage ships [11,12]. In contrast to economies of scale, another study observed that increasing passenger ship size increases unit price [13].

In addition, the daily operating expenses of the ships were investigated in another study [14]. However, because the cost calculations in this study were based on partially genuine statistics, the conclusions were insufficient to be extended to other firms. The claimed reason for this was that the SOs were unwilling to divulge the true cost data. In addition the expenses in each container slot of container transport ships were investigated using mathematical modeling and additional costing techniques [15]. Cost suggestions were provided to container transportation enterprises and ship charterers due to research conducted on a specific route. The study's shortcoming was stated to be that it was conducted in a certain route and that different results may be obtained in other regions.

In addition to prior studies, SOs have attempted to decrease expenses by lowering ship bunker consumption against rising oil prices and fuel consumption regulations [16]. This study examined the relationship between speed, route, and consumption using the stochastic linear integer programing model, and it was concluded that fuel cost may be lowered with the proper route and speed. Another author [17] utilized a mixed integer nonlinear programing model to optimize ship navigation in linear transport. It has been suggested that this could result in 6-10% improvement in both ship arrival times and prices. In addition to these studies, it was [18] attempted to find the ideal maintenance time policy in their study on ship engine maintenance expenses. In the MATLAB-simulated investigation, coding on probability analysis was done, and therefore optimal maintenance durations were identified. According to the study, ship engine maintenance expenses may be lowered by 11% each year.

Costing is crucial in transportation sectors other than sea transport, as it is in other industries. Cost studies at railway stations [19] and freight determination in train transportation were studied [20], and because of these studies, employment recommendations were made to firms. There are studies on the financial comparison of different airline companies [21], support, and guidance on the assessment of the freight/ticket price of the airline business operating a certain line in the aviation industry [22]. Furthermore, cost research attempts to raise airline company profitability ratios by integrating various mathematical and statistical methodologies [23]. There are studies undertaken with road transport firms, such as trip cost analysis of the bus company running on a certain route [24], empirical cost analysis, and suggestions for city bus and trolleybus services [25].

According to another study [26], precise estimation of expenditure items is critical not only for businesses but also for developing countries. While working on expenses, it is critical for the reliability of the research to establish and quantify overall costs rather than individual costs. In this regard, the ABC approach offers several applications. For example, it performed a cost analysis for truck transportation enterprises and developed a general financial framework for businesses [27]. Furthermore, by analyzing the supply management system in a non-profit hospital, a general health framework was developed [28]. However, as aforementioned, research in the literature on the shipping sector has been conducted on the optimization of individual cost categories. Contrary to the studies in the literature on the shipping sector, in this study, all cost factors that SOs encounter while transporting freight have been thoroughly investigated. More precise loading-specific costs are calculated using the general framework for SOs. The gaps in the literature were attempted to be filled in this way. Furthermore, unlike other studies in the maritime sector, ABC could assist enterprises in developing a sustainable cost structure by detailing the activities that impact costs using the ABC model [29].

3. ABC

ABC is a cost calculation method that takes into account the activities required for production or service while calculating the cost [30]. By assigning resources to activities and activities to cost objects depending on user usage, this modeling helps organizations understand the measurement costs and performance of activities, resources, and cost objects. It also helps identify causal links between cost drivers and activities [31]. This method, which emerged in the 1980s, has been used in various studies in many fields over the years. Such as; in health [32], manufacturing [33], banking [34], libraries [35], agriculture [36], and transportation [37]. Apart from the sectors, some studies have shown the ABC methods' impacts on management and decision-making progress. It was stated in the study [38] that different inventory quantities lead to different results in terms of management costs in the same period, which causes different results in the ABC model. In another study [39], authors explained that the rate of administrative adaptation to ABC remained at 24%, and 72% of them found themselves in traditional costing while eliminating the difference in facility costs, with statistical calculations.

The purpose of the ABC system is to determine the activities required for the production of services or products and to allocate these activities to the costs based on the amount of resource consumption [40]. In this model, cost objects consist of activities and activities consist of resources. Therefore, the model utilizes the two-step procedure defined below to place resource costs on cost objects, as demonstrated in Figure 1. Logic in Figure 1 is the underlying logic of the model, although ABC is not a single application method and may vary from company to company [41].

Step 1: This stage includes the distribution of resource drivers to activity centers in proportion to the activity performed.

Step 2: Cost items in the determined activity pools are collected on cost objects. The unit price is obtained by dividing the total cost by the total product produced.

On the other hand, the service and production sectors differ in the ABC implementation phase. The differentiation between sectors was mentioned in the study [42], and the reason for this difference is the fact that the service sector has more activity and activity producers than the production sector. Maritime transport includes more complicated operations. The first of these are operations that are not in other sectors, such as port operations, crew operations, and inspections.

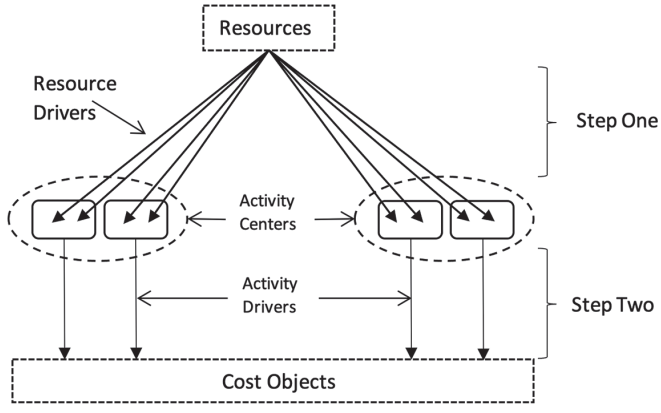

Figure 1. *Cost constitution steps in activity-based costing [22]*

In addition to its benefits, the ABC approach has drawbacks. The greatest difficulty is that a thorough analysis of the activities requires time. However, businesses are reluctant to adopt this strategy because of the significant financial resources that are moved. The main issues that businesses encounter while using the ABC technique are inadequate managerial support and a lack of coordination and integration of internal information systems [43].

3.1. Methodology of the Study

In this study, the ABC method was used to perform accurate cost calculations. Unlike other ABC studies, different possibilities were observed and interpreted with simulation support. The explanation of the models used in this study is as follows. To conduct a cost analysis for ship management companies, this study uses the advantages of the ABC method. A cost estimate study that takes into account all cost items has not been found in the literature, despite studies concentrating on various cost items in maritime transport. The research was conducted for the business operating a ship on a certain route to adapt this methodology to the maritime literature. Figure 2 illustrates the ABC flow diagram used in this research.

Step 1. Determination of Company Details: In the first step of ABC in this study, details of the company that is the subject of the study, such as company structure, number of employees, and departments, are specified.

Step 2. Determination of the Cost Object: In this step, information related to the voyage of the analyzed ship, such as route, duration, and amount of cargo, is determined.

Step 3. Determination of Direct Costs: This step specifies the direct costs that are added directly to the cost during the production of the service.

Step 4. Determination of Activity Centers and Cost Factors: This is the process of grouping the activities performed by the SOs company during service production according to certain characteristics.

Step 5. Determination of the Costs of Activity Centers: This is the process of allocating the expenses of ship management to the activity centers after the activity centers are determined.

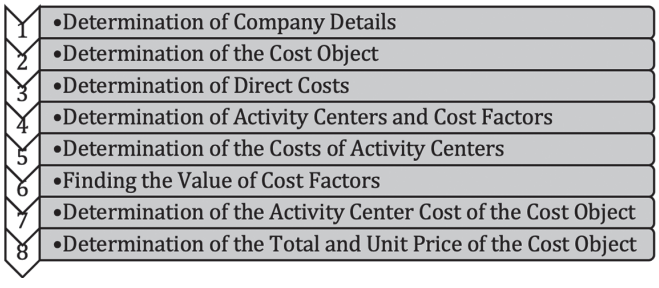

Figure 2. *Flow chart of ABC model in SOs companies*

Step 6. Finding the Value of Cost Factors; is the unit price calculation step obtained by dividing the costs of the activity centers found in Step 4 by each cost factor.

Step 7. Determination of the Activity Center Cost of the Cost Object: In this step, the total costs are calculated over the number of activities spent for the determined route.

Step 8. Determination of the Total and Unit Price of the Cost Object: By adding the total cost calculated in Step 7 and the direct expenses (Step 3) previously determined, the "Total Cost" of the voyage will be divided by the total amount of cargo carried, and the "Unit Price/Tonnage" will be found.

3.2. Application of the Model

This section presents ABC's proposed steps, which were mentioned in the previous section, with a case study.

Step 1. Determination of Company Details: X Ship Management company, where the study was conducted, is a company that performs transportation in all waters of the world with its 10 ships. Corporation X Ship Management owns all ships. Although it possesses ships of various tonnages, all of its vessels are bulk carriers. In this study, the transportation process in which the ship occurs on a certain route has been considered. The data obtained because of the study appear as the cost calculation for a specified monthly period.

It is possible to divide maritime companies into shoreside and shipboard companies according to their characteristic structure. The shoreside staff efficiently operates, manages, and maintains the fleet of ship management companies. The shipboard staff is responsible for the efficient operation of the ships.

The total number of people working in the company as land personnel is 35 and sea personnel is 228. The distribution of employees by department is shown in Figure 3.

Step 2. Determination of the Cost Object: The details of the voyage where the study was conducted are given in Table 1.

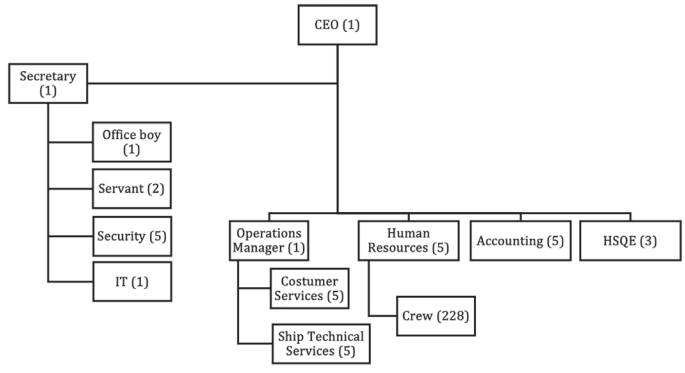

Figure 3. *Company Organizational Structure and Employee Distribution*

Table 1. *Details of the voyage*

Details	
Port of loading	Tekirdağ/Türkiye
Port of discharge	Bari/Italy
Quantity of shipment	100,000 tons
Description of the goods	Bulk cargoes

Figure 4 demonstrates the route of the study. It starts from Tekirdağ/Türkiye to Bari/Italy. The route image was obtained from the NETPAS program, in which the bunker calculation was performed. The NETPAS program's route diagram also indicates that it takes roughly three days to travel the distance between Tekirdağ and Bari. Seven journeys were planned, each lasting three days: three days out and three days back. The simulation tool was used to examine several scenarios, accounting for factors such as weather, Bosphorus crossings, port disruptions, and maritime traffic density. It was discovered that the average length of the entire voyage was 28 days.

Step 3. Determination of Direct Costs: Direct costs are costs that can be directly attributed to the service or product and can be easily calculated [44]. In maritime transportation, there are some cost items to which the owner of the ship is exposed even if it does not perform the cargo transportation process. Therefore, in this study, the cost items that the ship will be exposed to whether it is transported or not are considered direct costs. The direct cost items used in this study are shown in Table 2. Data in Table 2 were obtained from a real shipping company that operates its own ships.

Step 4. Determination of Activity Centers and Cost Factors: This is the process of grouping the activities performed by the SOs company during service production according to certain characteristics. Table 3 shows the activity centers determined in this study.

The details of the activity centers are as follows:

C1 - Load Finding: This is the first element required for maritime transport. This section includes activities such as sales-marketing transactions, pro forma price offers, and carriage contracts. In general, it can be done with hundreds of mail or phone calls daily in ship enterprises.

Figure 4. *Demonstration of the route used in the study*

Table 2. *Direct costs*

Direct Costs	
1. Cabin Store	17. Modifications
2. Chemical and Gas	18. Nautical Pub and Charts
3. Crew Clothing	19. Navigational Equipment Survey and Maintenance
4. Crew Flight	20. Oil (Lubricant)
5. Crew Handling	21. Other
6. Crew Payroll	22. Paint
7. Deck Maintenance	23. Provisions
8. Deck Store	24. Registration-Flag Expenses
9. Dry Dock	25. Ropes
10. Engine Maintenance	26. Safety
11. Engine Store	27. Spare
12. Initial Stores	28. Spare and Store Handling
13. Insurance	29. Stationary
14. Inventory	30. Survey
15. LSA and FFA Inspection	31. Telecom
16. Medical and Support	

Table 3. *Activity centers*

Activity Code	Activity Center
C1	Load Finding
C2	Customer Operation
C3	Port Operation
C4	Ship Operation
C5	Inspection
C6	Crewing

C2 - Customer Operation: This section covers sharing all the situations concerning the customer with the customer for the agreed loading operation and organizing the organization. The loading operation for the agreed loading, the communication of the ship, voyage, and cargo details to the parties, keeping in touch with the customer during loading, transportation, and unloading, issuing the final invoice, calculating the demurrage/dispatch payments that may occur at the end of the loading, and performing the invoice processes are discussed in the customer operation section.

C3 - Port Operation: Ensuring the coordination at the ports where loading and unloading occur takes place in this part. It is ensured that the parts related to the ship, such as communication with the agency in the ports, communication with the ship, the realization of inspections, if any, and their organization, and the delivery of solid and liquid wastes,

are carried out in a controlled manner. Here, the customer is informed about the parts that concern the customer by interacting with the customer operation department.

C4 - Ship Operation: Examines activities during the transportation of loaded goods. Ship-related events. It covers reports from the ship and unusual circumstances.

C5 - Inspection: These are the activities carried out in the case of regular or random inspections such as port inspection, classification inspection, and ISM inspection. This includes communication with inspection bodies, interactions, and activities during the inspection.

C6 - Crewing: This section covers the operation of the ship's boarding and disembarking crew. Crew planning, transportation and accommodation activities, crew certification, and training are reviewed in this section.

In this step of the ABC method, with the determination of the centers, the activities carried out for service production are also distributed to the centers. The activities carried out to produce the service are grouped under 3 main headings. These are the "Customer Operation", which communicates with the customer during cargo transportation, "Technical Operation", which connects the ship and the office for the ship to complete its course, and "Ship Operation", which establishes the connection between the seafarers and the ship. The distribution of activities to activity centers according to the main service production sites is given in Table 4, Table 5, and Table 6.

Step 5. Determination of the Costs of Activity Centers: The process of allocating expenses among the activity centers identified in step 4 was initiated. Financial data obtained from real ship management companies. While distributing the indirect costs, Table 7 was created by considering the conditions necessary for the voyage. Table 7 shows the distribution of indirect costs by activity centers and cost drivers. In this spot, expenditures are allocated to the participating units following their use. For illustration, office supply depreciation costs are distributed according to the amount of equipment in each activity center. There are 35 computers at the company. According to the number of computers in the departments, they were divided. It was found that it would cost $41.46 for the load-finding activities and $82.93 for the crew activity center. The proportioning item used to distribute the total amount of each cost item to the activity centers is shown in the Cost Driver column of Table 7.

Step 6. Finding the Value of Cost Factors: The calculation of unit prices of activities in the determined activity centers is accomplished in this step. As stated previously, the simulation of the study was repeated 60 times for a 1-month activity period using the ARENA simulation. This helped to determine the amount of activity with sparse, average, and intensive transactions that the firm may encounter in a month. Assuming that all activities are conducted via e-mail, unit price calculations are made. During the calculation, the average monthly activity amount was converted into an annual amount, and the unit price was determined as the percentage of the activity amount spent by each activity center. The average activity amounts and unit prices of each activity center are shown in Table 8. The ratio of the average activity amount to the total average activity and the percentage annual activity amount of each activity center are found. Because the total cost is calculated annually, the calculation was made over the annual average mail. By dividing the total figures of each activity center specified in Table 7 by the annual number of activities, the unit prices of each activity can be found separately according to the activity centers. As an example, according to the simulation results, an average of 6,556 emails were received per month. On average, 548 of these e-mails were related to the shipment in the study. The calculation example of C1 is as follows. C1's approximate unit price are calculated as follows:

Table 4. *Customer operation activity analysis, activity centers, and cost factors*

	Activity	Activity Factor	Activity Center
Customer Operation	New shipment mails	Email	C1
	Port Cost requests	Email	C1
	Mail not available for a new shipment	Email	C1
	Bidding to the customer	Email	C1
	Contract approval	Email	C1
	Notification of ship details to the customer	Email	C2
	Notification of daily ETA information to the customer	Email	C2
	Laycan control with the customer	Email	C2
	Laycan agreement mail	Email	C2
	Notification of berthing details to the customer	Email	C2
	NOR information to the customer	Email	C2
	Report SOF information to the customer	Email	C2
	Sending samples of port documents to the customer	Email	C2
	Delivery of the bill of lading to the customer	Email	C2
	Send departure information to the customer	Email	C2

- 142/548 = 0.26 (percent of C1)
- (6,556 x 12) 0.26 = 20,386 emails (yearly activity for C1)
- 6,410.05 / 20,386 = 0.31 USD/email (unit price of C1)

Step 7. Determination of the Activity Center Cost of the Cost Object: In this step, the total indirect costs are calculated over the activity amounts spent for the determined voyage. Indirect cost amounts determined over possible minimum, average, and maximum activities in Table 8 are given in Table 9.

Step 8. Determination of the Total and Unit Price of the Cost Object: In this step, the total cost of the voyage, which is determined by adding the direct, voyage, and indirect costs, is determined. The obtained results are shown in Table 10.

Table 5. *Technical operation activity analysis, activity centers, and cost factors*

Main Service Production	Activity	Activity Factor	Activity Center
Technical Operation	Inform the agency about port requirements	Email	C3
	Sending a bill of lading sample to the agency	Email	C3
	Sending agency details to the company for the needs	Email	C3
	Notifying the port of the seafarer information that will participate in the ship	Email	C3
	Learning the berthing details from the agency	Email	C3
	Monitoring agency emails	Email	C3
	Information to the agency about the company that will sell the material to be sent to the ship	Email	C3
	Supply of port arrival documents required for the destination port	Email	C3
	Submission of port arrival documents to the port authorities	Email	C3
	Arrangement of the port documents	Email	C3
	Reporting DPA information to the port	Email	C3
	Get a quote for the provision wishless	Email	C4
	Unforeseen PSC control information from the captain	Email	C4
	Notify Dpa for PSC	Email	C4
	Notifying the ship of the information about the seafarer to embark	Email	C4
	Notification of new shipment details to the ship	Email	C4
	Get quotes for store items	Email	C4
	Get spare parts to offer for ship urgent needs	Email	C4
	Get a fuel quote for the voyage	Email	C4
	Inform the ship about refueling	Email	C4
	Sending the information of those who want to disembark the ship to Human Resources	Email	C4
	Notifying the fuel company about the port/anchor area for refueling	Email	C4
	Checking fuel analysis details from the ship	Email	C4
	Notifying the port details for the seafarer who will disembark	Email	C4
	Reading the request mail of seafarers who want to disembark	Email	C4
	Notify the ship of the information about the seafarer to embark	Email	C4
	Sharing voyage details with HR for embarkation procedures	Email	C4
	Act for deficiencies in surveys	Email	C4
	Providing inspection information to the ship	Email	C4
	Inform the agent about refueling	Email	C4
	Reading health needs mail	Email	C4
	Inform the Agency about health needs	Email	C4
	Forward future loading information to the ship	Email	C4
	Review of the inspection report	Email	C4
	Reading the DPA report	Email	C4
	Sending an ambulance for a health problem	Email	C4

Table 6. *Ship operation activity analysis, activity centers, and cost factors*

	Activity	Activity Factor	Activity Center
Ship Operation	Request checklist from the ship for the survey	Email	C5
	Checklist control	Email	C5
	Forwarding the survey details to the agency authorities	Email	C5
	Flag state calls for an inspection	Email	C5
	Notifying agency for flag state inspection	Email	C5
	Notifying the port of office worker information to accompany the survey	Email	C5
	DPA's date adjustment for internal audit	Email	C5
	DPA report preparation and submission after the audit	Email	C5
	Notify the ship about the internal audit	Email	C5
	Post-audit report preparation	Email	C5
	Attending the port for the survey (DPA)	Voyage	C5
	Notifying the technical team of the seafarer information who will participate in the ship	Email	C6
	Obtaining voyage information for the seafarer who will disembark	Email	C6
	Checking eligibility for the disembarking seafarer	Email	C6
	evaluation after an interview with the intern	Candidate	C6
	Notifying interns of their admissions	Candidate	C6
	Evaluate intern applications	Candidate	C6
	Requesting the necessary documents for those who are suitable for an internship	Email	C6
	Evaluating job applications	Candidate	C6
	Checking and making appropriate the missing participation documents	Candidate	C6
	E-mailing new staff that has been hired	Email	C6
	Invite interns for interviews	Email	C6
	Number of interns interviewed	Email	C6
	Providing ship information to the seafarer who will embark	Email	C6

Table 7. *Activity centers and cost drivers (USD)*

Costs	Cost Drivers	C1	C2	C3	C4	C5	C6	Total
Telecommunication expenses	Number of personnel	144.40	144.40	108.30	90.25	54.15	36.10	577.62
Office overall expenses	Number of personnel	51.86	51.86	46.09	46.09	51.86	57.62	305.37
Cargo and postal services expenses	Number of shipments		190.01					190.01
Chamber and fee expenses	Number of ships				267.15			267.15
Bank expenses	Number of shipments	14.44	14.44	14.44	14.44	14.44	14.44	86.64
Meal allowance	Number of personnel	508.25	508.25	508.25	508.25	609.90	1,016.50	3,659.41
Workplace rental expenses	Meter square	311.91	311.91	277.26	277.26	311.91	346.57	1,836.82
Accounting expenses	Number of personnel		534.92		534.92			1,069.85
Transportation expenses	Number of cars	127.74	127.74	127.74	127.74		255.48	766.45
Consulting expenses	Number of ships				75.34			75.34
Vehicle maintenance expenses	Number of cars					53.59		53.59
Gross salary	Number of personnel	4,192.02	4,496.93	4,189.35	4,189.35	17,008.80	6,551.03	40,627.47
Vehicle insurance and policy expenses	Number of cars					104.21		104.21
Notary expenses	Number of agencies			40.19	40.19			80.39
Fuel expenses	Number of cars					1,965.09		1,965.09
Representation and entertainment expenses	Number of ships	385.08	385.08	385.08	385.08	385.08	385.08	2,310.47
Transportation charges of seafearers	Number of seafarers	491.36	491.36	491.36	491.36	491.36	491.36	2,948.16
Depreciation (Office tools)	Number of office tools	41.46	41.46	41.46	41.46	49.76	82.93	298.55
Finance expenses	Meter square	141.52	141.52	141.52	141.52	141.52	141.52	849.10
Total		**6,410.05**	**7,439.88**	**6,371.05**	**7,230.41**	**21,241.66**	**9,378.64**	**58,071.69**

Table 8. *Unit prices of the activity centers*

Activity Code	Activity Center	Sparse	Average	Intensive	% Activity	Email quantity	Unit price (USD)
C1	Load Finding	14	142	380	26	20,386	**0.314434**
C2	Customer Operation	110	115	123	21	16,510	**0.450629**
C3	Port Operation	98	134	221	24	19,237	**0.331187**
C4	Ship Operation	16	31	76	6	4,450	**1.624811**
C5	Inspection	8	15	19	3	2,153	**9.866077**
C6	Crewing	63	111	209	20	15,935	**0.588556**
TOTAL		309	548	1,028	100	78,672	
Simulation results		709	6,556	19,054			

Table 9. *Indirect costs according to ABC*

	Sparse	Average	Intensive
Indirect costs (USD)	228.43	404.54	682.05

Table 10*. Unit prices per tonnage for sparse, average, and intensive activities ($)*

		Yearly	Monthly	Daily	Voyage	Unit prices per tonnage
Costs of Sparse Activity	Direct Costs	3,444,831.82	287,069.32	9,437.90	264,261.07	2.64
	Voyage Costs				531,914.93	5.32
	Indirect Costs				228.43	0.00
	Total	3,444,831.82	287,069.32	9,437.90	796,404.44	7.96
Costs of Average Activity		**Yearly**	**Monthly**	**Daily**	**Voyage**	**Unit prices per tonnage**
	Direct Costs	3,444,831.82	287,069.32	9,437.90	264,261.07	2.64
	Voyage Costs				531,914.93	5.32
	Indirect Costs				404.54	0.00
	Total	3,444,831.82	287,069.32	9,437.90	796,580.55	7.97
Costs of Intensive Activity		**Yearly**	**Monthly**	**Daily**	**Voyage**	**Unit prices per tonnage**
	Direct Costs	3,444,831.82	287,069.32	9,437.90	264,261.07	2.64
	Voyage Costs				531,914.93	5.32
	Indirect Costs				682.05	0.01
	Total	3,444,831.82	287,069.32	9,437.90	796,858.06	7.97

4. Results

In this study, the cost of a ship operating company was calculated using the ABC method. Apart from the other sectors, in addition to the high costs faced by a ship even if it does not carry cargo, costs belong to only a determined voyage. These costs are called voyage costs. In addition to direct and voyage costs, cost items such as office workers and transactions, which are also used in this calculation, have also been included in the calculation as indirect cost items. In companies operating ships using the traditional costing method, indirect cost items are calculated by dividing the ships operated by the company equally. Table 11 shows the unit price and total cost amounts obtained from the traditional costing and ABC methods.

According to the data in Table 11, while the total cost of 100,000 tons of cargo is $803,491.66 according to the traditional costing method, the cost of the ship is $796,404.44 in an average activity period concerning the ABC method. This shows that the cost of this ship, which carries 100,000 tons of cargo by making 4 voyages in 1 month, is $6,911.11 less than ABC. It is concluded that even the same loading in a very busy period costs $6,633.60 less than the cost amount in traditional costing. Considering that the total cost incurred by the firm during the year has not changed, the $7,000 difference in this calculation indicates

***Table 11**. Traditional Costing and ABC Results*

	Traditional Costing ($)	Activity-Based Costing		
		Sparse ($)	Average ($)	Intensive ($)
Per tonnage	8.03	7.96	7.97	7.97
Total Shipment	803,491.66	796,404.44	796,580.55	796,858.06
Difference	0.00	-7,087.22	-6,911.11	-6,633.60
Percentage		-0.88	-0.86	-0.83

that the firm's cost in other shipments is higher than their calculations.

5. Discussion and Conclusion

It is a mode of transportation that possesses unique aspects of marine transportation. In this work, a marine transport company's operations are analyzed and simulated while considering its distinctive structure. The ABC method developed by Cooper and Kaplan [45] was utilized to interpret the simulation results, and the findings were evaluated.

In the fiercely competitive maritime sector, activities were decided upon by negotiating with corporations to establish the proper cost structure. Whenever there was a lack of data, assumptions were formed, as was the case with the previously mentioned [14] study. These assumptions were developed because of a lack of data as well as the reluctance of businesses, as seen in the study [46], to offer information on certain topics (such as financial information and operations).

This research examined the international marine transport process of a ship management company operating in Türkiye, which consists of 4 voyages between Tekirdağ and Bari. These 4 voyages lasted a cumulative 28 days. ARENA simulation was used to model the activities indicated using the ABC method. To improve the precision of the simulation results, a period of 5 years (60 months) was simulated. In this way, it has been determined how the expenses may vary depending on the sparse, average, and intensive period by examining the many variables that the company may encounter during this transportation voyage. The results of the 60-month simulation obtained using the ABC method were used to calculate the voyage cost. It is determined that the companies accomplish this transportation at a cost of approximately $7,000 less for this transportation voyage when the ABC results are compared to the traditional costing method. This outcome shows that the company might be more competitive during the bidding stage. Additionally, calculations are performed for yearly expenses. It might be claimed that the company transports $7,000 more on other shipments, given that the annual total cost remains the same. The reason for this is that the traditional costing method performs volumetric cost calculation. Since the ABC method considers the activities performed during service production, it does not include costs in volumetric service production. For this reason, the shipping company whose cost calculations were made in this study could not see that it incurred more costs than expected in other shipments because it did not consider the activity amounts in other shipments. The company's cost estimations diverge from one another and do not adhere to the idea of a sustainable financial structure. In addition to providing financial data, this modeling facilitates simulation updates and scenario analysis for SOs. International regulators have imposed obligations on SOs, one of which is decarbonization, which is a contemporary issue. By considering the potential outcomes while performing these duties, SOs will be better able to make strategic decisions that look forward.

The fact that the ABC approach is frequently used in other transportation techniques, despite the absence of studies using it in the field of maritime transport, speaks volumes about the significance of the topic and modeling. As instances of its significance, studies on the rail [19], road [47], and air [21] transportation sectors might be presented. These studies' recommendations to companies demonstrate the critical role that modeling can play in assisting companies to grow a sustainable cost structure.

As mentioned by earlier investigations, a closer examination of the ABC method stages is required to improve the quality of the studies. As a result researchers must collaborate with businesses for a longer duration and in a demanding setting. This might be described as one of the time- and money-related drawbacks of modeling. However, this undesirable circumstance, which is expressed next to the intended results, may be tolerated.

In this study, the outcomes gained through simulation indicate both the progress of modeling and its relevance to the marine industry. Modeling will be a pioneer in their implementation, especially in the marine sector where there are not only SOs but also various maritime phenomena, including brokerage, agency, and port management. In terms of modeling, it has been observed that simulation makes it simpler to find the idle capacity, which is challenging to determine using the ABC method. Even though the Time-Driven ABC technique makes it

simpler to calculate idle capacity [48], simulation support also has additional benefits, including making it simple to determine idle capacity.

To obtain more comprehensive data for future studies, involving other stakeholders in the maritime sector will greatly enhance the findings. It goes without saying that obtaining precise activity data on the ship will enhance modeling and outcomes. As noted in other studies [49], company managers' comprehension of modeling and its necessity is the most important requirement for all of these to occur.

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