FLEET OPTIMIZATION OF OFFSHORE SUPPLY VESSELS TO SUPPORT LOGISTICS OPERATIONS ACTIVITIES FOR OIL AND GAS PRODUCTION USING INTEGER PROGRAMMING METHOD

OPTIMASI ARMADA OFFSHORE SUPPLY VESSELS DALAM MENUNJANG KEGIATAN OPERASI LOGISTIK PRODUKSI MINYAK DAN GAS MENGGUNAKAN METODE INTEGER PROGRAMMING

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Abstract

Oil and gas production activities in offshore cannot be done without the roles of Offshore Supply Vessels as a driver of logistic activities. Vessel operation is considered as one of the largest cost components in offshore oil and gas production activities. Any effort to minimalize vessel operation costs will give significant effect to the company's total operation costs. This research conducts how to optimize Offshore Supply Vessels of CNOOC SES Ltd using Integer Programming by formulizing mathematical model of Offshore Supply Vessels operation first. Decision variable values of vessel mathematical model are gained using Lingo 8.0 software. Optimization process gave reduction in daily operation costs around 3.12% or equivalent to US$ 3,495.

Keywords: Integer programming; oil and gas; optimization; logistics; offshore supply vessels; mathematical model; Lingo 8.0.

Abstrak

Kegiatan produksi minyak dan gas di lepas pantai tidak dapat dilaksanakan tanpa peran vital dari armada kapal pemasok lepas pantai (Offshore Supply Vessels) sebagai penggerak kegiatan logistik. Operasi armada kapal ini merupakan salah satu komponen biaya terbesar dalam kegiatan produksi minyak dan gas lepas pantai. Setiap usaha untuk meminimalisasi biaya operasi armada akan memberikan dampak yang signifikan terhadap total biaya operasional perusahaan. Dalam penelitian ini dilakukan proses optimasi terhadap armada kapal pemasok lepas pantai perusahaan CNOOC SES Ltd. Metode yang digunakan adalah integer programming dengan terlebih dahulu memformulasikan model matematis dari operasi armada kapal. Nilai variabel-variabel keputusan dari model matematis armada diperoleh dengan bantuan perangkat lunak optimasi Lingo 8.0. Proses optimasi menghasilkan pengurangan biaya operasi harian sebesar 3,12% atau setara dengan US$ 3.495.

Kata kunci : Pemrograman Integer, ,minyak dan gas, optimisasi, logistik, kapal pasok lepas pantai, model matematika, Lingo 8.0.

Diterima (received) : 14 Februari 2019 , Direvisi (revised) : 01 Maret 2019 ,
Disetujui (accepted) : 05 Maret 2019

INTRODUCTION

Offshore oil and gas production activities are capital intensive activities, downtime at these production facilities will cause a large potential loss of profit. Increasing oil demand, soaring costs and market competition have pressured oil companies to find innovative solutions. For this reason, an effective response to demand for drilling rig supply items and production platforms is a major problem in offshore logistics in the present[1), one of which is the availability of transportation facilities in the form of offshore supply vessels. Therefore the provision of reliable transportation facilities is very important and critical.

Offshore oil and gas production activities cannot be carried out without the vital role of offshore supply vessels. The operation of the offshore supply vessel fleet is one of the biggest cost elements in the operations of oil and gas companies[1)]. These supplier fleets are generally leased by oil companies. In practice, the scheduling activities and route determination of the fleet are the responsibility of the leasing oil companies[2)]. The management of this supply fleet optimally is expected to reduce the cost of the operation.

This research was conducted at the oil and gas company CNOOC SES Ltd. This company is engaged in the upstream oil and gas sector. The operating area is located on the Java Sea or more precisely in the Southeast area of the island of Sumatra (SES = South East Sumatra). This operating area is divided into three regions, namely South, Central and North, with a total production platform of the three areas being around 70 platforms. In order to meet operating needs, the company operates one port or shore base in Kalijapat-4, Tanjung Priok, Jakarta, where all the traffic of goods going in and out for operational purposes is centered in this place[3)].

Offshore operations include production, drilling, well maintenance (work-over) and facility maintenance activities. To support these operations, logistics activities play an important role. At CNOOC SES Ltd, the offshore logistics operations are supported by a shipping fleet consisting of 7 Anchor Handling Tug Supply (AHTS) and 1 Landing Craft Tank (LCT), with a fleet control center located in Jakarta[3)].

Problems identified in the operation of the shipping fleet at CNOOC SES Ltd include the following:

- The management of the supply vessel fleet has not been well formulated, especially related to the calculation of the suitability of the number of operating needs and the number of supply vessels provided.
- High operational costs, especially for fuel components.
- The absence of a quantitative planning process on the placement of vessels on existing assignments.

The purpose of this research is to try to overcome the above problems by carrying out the following steps:

- Perform quantitative calculations of actual fleet requirements based on the company's operating needs during normal operating conditions, that is, in conditions consistent with assumptions on the boundaries of the problem.
- Obtain a mathematical model of the operation of a supply ship fleet at the company CNOOC SES Ltd.
- Conducting an optimization process on the mathematical model of the supply vessel fleet to minimize the operational costs of the supply fleet during normal operating conditions.

The next section of this paper will explain the materials and methods, followed by the results and discussion, and concluded with conclusions from the results of the research.

MATERIALS AND METHOD

A. Theoritical Review

Logistics in Supply Chain Management

Harrison, van Hoek and Skipworth define supply chain management as a partner network that jointly converts basic (upstream) commodities into finished products (downstream) that are valued by end consumers and also manage profits at each level[4)]. The definition of logistics, according to Harrison, van Hoek & Skipworth includes the task of coordinating the flow of material and information in the supply chain system to meet the needs of end consumers[4)]. Whereas APICS defines logistics broadly as art and science to obtain, produce and distribute material and products in the right place and in the right amount[5)]. Whereas the objectives of logistic management are to obtain operating efficiency through the integration of all material procurement, movement and storage activities[6)].

Logistics is a very important enabler factor of supply chain management, because the level of customer satisfaction is determined by the management of material flow and information in the supply chain. Given the important role of the logistics function in supporting the supply chain system, the planning of the logistics network needs to be done well.

Logistics Network (Transportation)

The design of the logistics network (transportation) will affect the performance of the supply chain through the type of infrastructure development, in which decisions on transportation operations related to scheduling and route determination are made. A well-designed transportation network will make the supply chain have a good response rate with low operating costs.

According to Chopra and Meindl, there are 6 alternative types of logistical network design (transportation), namely direct shipment network, direct delivery with milk runs (direct shipping with milk runs), shipping through distribution centers (DC), shipping through distribution centers with milk-runs, shipping via line-haul with cross-docking, and combinations of several network types above[7)].

The right transportation or distribution network can be used to achieve various supply chain objectives, starting from those that aim to achieve low costs to high responsiveness. Therefore, even though in the same industry category, one company with another company might apply a different type of transportation network (distribution) depending on the purpose of their supply chain[8)].

In the logistics network planning process, it requires data, analytical techniques, software and information systems. After the required data is available, the next step is to find the best network design process. The search process is a complex step and usually requires the help of mathematical modeling or computer simulation. Some methods used in the industry include optimization models, computer simulations, heuristic models and expert systems, and decision support systems[9)].

Integer Programming

When viewed from the complexity of the modeling, the optimization method is considered the most appropriate to use in this research. The method of solving problems through integer programming can be a solution to the problems of the supply fleet.

The Integer Programming Model is a model that has objective boundaries and identical functions with linear programming. The differentiating factor lies only in one or more decision variables which must be round or integer[10)].

Integer programming consists of three types, namely:

a. Pure integer programming, where all variables must be integers.
b. Mixed-Integer Programming, where not all decision variables are integers.
c. One-zero integer programming, is a special case where all decision variables are integers that have a value of 1 or 0.

In integer programming modeling, integer variables must be considered which arise from (i) logical conditions and (ii) nonlinearities[11)]. Integer programming can be used if subdivision is not possible like half an airplane or renting a quarter of people[5)].

Procedure for Settling Integer Programming with the Branch and Bound Method

Branch and bound method is an integer programming solution approach based on the principle that the total set of possible solutions can be partitioned into a subset of smaller solutions. The idea is to partition feasible areas into more manageable subdivisions and then if needed, further subdivision solutions can be carried out. In general there are several ways to divide decent areas and as a consequence there are a number of brand-and-bound algorithms[11)].

Transportation Problems

Transportation problems often arise in the process of planning the distribution of goods or services from the source location to the location where the request originates. In general, the number of goods from the source location is limited and the number of items at each location of demand is known[12)].

The objective function of transportation problems in general is to minimize shipping costs from source locations to destination locations. According to Winston[13)], in general transportation problems can be described with the following information:

1. The set of ***m*** source / supplier points *m* from which the goods originated. The source point ***i*** can supply as much as the unit of goods.
2. The set of ***n*** points of demand where goods are sent. Point ***j*** can accept at least ***dj*** units of goods.
3. Delivery of goods from the source point ***i*** to the point of demand ***j*** will cause variable costs ***cij***.

If ***xij*** is the number of units sent from the source point ***i*** to the request point ***j***, then the general formulation of the transportation problem is as follows.

Objective Function:

$$Min = \sum_{i=1}^{i=m}\sum_{j=1}^{j=n} c_{ij}x_{ij} \qquad (1)$$

With the following constraints:

$$\sum_{j=1}^{j=n} x_{ij} \le s_i \qquad = 1, 2, \ldots, m) \qquad (2) \text{ (source constraints)}$$

$$\sum_{i=1}^{i=m} x_{ij} \ge d_j \qquad (j = 1, 2, \ldots, n) \qquad (3) \text{ (demand constraints)}$$

Where:

$$x_{ij} \ge 0 \qquad (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)$$

If the number of sources is equal to the number of requests, it can be said that the transportation problems that occur are balanced transportation problems.

Assignment Problems

Assignment problems can arise in a variety of decision-making conditions, where common problems include allocating a machine to work on a particular task, placing marketing personnel in a particular area, determining contract allocations to bidders, and so on. Specifically, the thing to be achieved in the assignment problem is minimizing costs, time or profit maximization from the assignment arrangements from a set of existing activities.

The assignment problem can be mathematically formulated as follows[14].

Objective Function:

$$Minimize Z = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad (4)$$

With the constraints as follows:

$$\sum_{i=1}^{n} x_{ij} = 1 \;\; for\, j = 1, 2, \ldots, n \qquad (5)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \;\; for\, i = 1, 2, \ldots, n \qquad (6)$$

With:

$$x_{ij} = 0 \; or \; 1 \; for \; all \; i \; and \; j$$

Where:

x_{ij} = assignment of resource ***i*** to activities ***j***

c_{ij} = cost associated with assigning resources ***i*** to activities ***j***

In the assignment problem, as stated in equations 4, 5 and 6, it can be seen that this problem is a balanced assignment problem because the amount of activity equals the number of resources.

The assignment problem is a special case of transportation problems, where the number of source points with the demand points is the same, m = n. If $a_1 = 1$ for *i* = 1, 2, ..., n is the availability of resources, and $b_j = 1$ for *j* = 1, 2, ..., m is the required demand, then the statement can be expressed mathematically as follows.

$$\sum_{i=1}^{n} a_i = \sum_{j=1}^{n} b_j = n \qquad (7)$$

B. Research Methodology

This research activity is carried out by following the steps:

- Data collection, which includes primary data and secondary data.
- Model formulation, by formulating mathematical models of supply vessel fleet operations, and testing mathematical models.
- The optimization process, which is done by using field operation data into a mathematical model and then carried out sensitivity tests.

The data used in this research are primary and secondary data. Primary data was taken through direct observation of shipping operations by observing the shipping fleet operations so that the mapping of supply vessel fleet problems and understanding of the operational patterns of the supply fleet were obtained.

Secondary data was obtained from daily reports on the fleet operations at CNOOC SES Ltd. Data retrieval is carried out in the operating room of the fleet controller at the Logistic and Marine Operation department (LMO), where at the center of this control the operation of ships is monitored and operating parameters are recorded. The focus of data collection is as follows:

- General routes for the movement of ships in the offshore area of CNOOC SES Ltd.
- Ship operating cycle consisting of standby time, cruising, loading and unloading and

bunkering (water or fuel transfers from or to the ship).
- The average speed of the ship during cruising.
- The level of fuel use.
- The level of need for material delivery to or out of the operational area of CNOOC SES Ltd.

Model Formulation

Models are representations of actual objects or situations which can be presented in various forms. One form of model presentation is in the form of mathematical equations[15].

Modeling is done after the data is considered sufficient and the operating patterns are understood. The results of problem identification will then be formulated into objective functions, while operating patterns are formulated into model constraints.

Important variables of objective function and boundaries are obtained from the results of identifying operating data parameters. The identification process is carried out by filtering the data to distinguish parameters that have a significant effect on parameters that do not have a significant effect on objectives.

To guarantee its accuracy, the model will be tested by entering the actual operational parameters into the model and then comparing whether the output produced has represented the actual condition or not. If proven formulated models are not accurate, the model formulation process will be repeated until a certain minimum level of accuracy can be met.

Optimization Process

After the model of the supply vessel fleet system is obtained, the next step is the process of optimization of the objective function (minimization in this case). The optimization process will use an integer programming method, where the search process for decision variables is aided by Lingo 8.0 optimization software.

Linggo 8.0 is software designed to efficiently create and complete linear, non-linear (convex and non convex / global) optimization models, quadratic, limited quadratic, second order cones and integers[16]. This Linggo 8.0 software was made by Lindo System Inc. based in Chicago, Illinois, United States.

Before the optimization process was carried out by Lingo 8.0 software, the transformation process from the mathematical model of the problem must be done to the programming language. The validation of the transformation process is carried out during the process of compiling syntax by software and also is done manually checking for the compatibility of mathematical logic.

The decision variables resulting from the optimization process will then be tested for feasibility through checking whether the variables still meet the model boundaries or not. If the optimization solution has met the feasibility test, then the next process is to conduct sensitivity testing. Sensitivity testing on this research is carried out by doing + 10% and -10% variations on decision variables to simulate uncertainty conditions.

RESULTS AND DISCUSSION

A. Research Results

Observation of Fleet Operations Activities

From the observation of the operational data of the company's shipping fleet from January 2011 to March 2013, the average daily weight of material transported by the CNOOC SES Ltd fleet was obtained at 129.13 tons. The distribution of material flows can be seen in Table 1 below.

Table 1.
Material Flow Distribution January 2011 - March 2013[17]

From	To	%
KJ4	Pabelokan	27.54%
	P. Excelcior	11.97%
	C221	1.91%
	C222	1.94%
	PTM	8.82%
	C223	4.54%
Pabelokan	KJ4	9.70%
	C221	0.37%
	P. Excelcior	5.13%
	C222	0.36%
	PTM	3.61%
	C223	0.30%
P. Excelcior	KJ4	3.84%
	Pabelokan	0.76%
PTM	KJ4	1.15%
	Pabelokan	0.76%
Others		17.31%
Total		100.00%

Based on observations, routes from the CNOOC SES Ltd shipping fleet can be described as shown in Figure 1. From the figure, it can be seen that there are five main routes, where one route uses the Landing Craft Tank (LCT) / Supply Cargo Vessel (SCV) ship type) and the other four routes are routes to Anchor Handling Tug Supply

(AHTS). In addition to serving material transfers between locations offshore, the CNOOC SES Ltd. shipping fleet also serves the activities of moving barges from a work location to another work location and assists in the operation of drilling rigs.

From the Figure 1 it can also be concluded that the type of transportation network used by CNOOC SES Ltd in the offshore logistics system is a combination of shipping through a distribution center (DC) with milk-runs (non-critical goods) and with direct shipment for critical items.

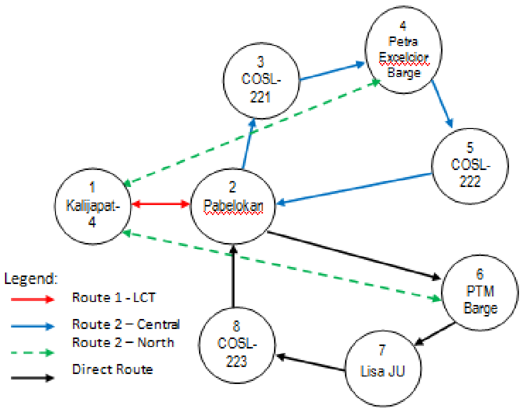

Figure 1.
Chart of CNOOC SES Ltd Shipping Fleet Routes[18)]

The operations activities of CNOOC SES Ltd are supported by a shipping fleet consisting of 1 (one) LCT and 7 (seven) AHTS. The vessels are obtained through a leasing system from several companies with specifications that can be seen in Table 2 below.

The Formulation Process of the Shipping Fleet Model

1. Mapping Important Variables

Important variables of shipping fleet operations are as follows:

S_m Daily rental fees of ship number **m** (US$)
R_m Binary logic if ship number **m** is hired, (0 = no /1 = yes)
F_{km} Fuel consumption of ship number **m** during cruising for assignment **k** (liter/km)
G_{km} Fuel consumption of ship number **m** during standby untuk penugasan **k** (ltr/hr)
D_k DIstance from assignment **k** (km)
A_k Assignment type
L_{km} Binary logic for usage of ship **m** on assignment **k** (0 = no /1 = yes)
C_m Ship cruising speed **m**
T_m Ship *towing* speed **m**
I_{km} Vessel **m** idle time on assignment **k** (hour)
M The number of ships in the fleet
K The number of assignments

Where the L_{km} variable is the decision variable of the optimization process.

For complete assignment groupings, see Table 3 below.

Table 2.
Shipping Fleet Specifications[18)]

No	Vessel Name	Type	DWT (ton)	Fuel Consumption (Liter/hour)				Rental Cost /day (US$)	Capacity			
				Cruising	Full Speed	Towing	Stand-by		Deck space (m2)	Deck Cargo (ton)	Fuel Tank (kL)	Water Tank (ton)
1	Abigail Sunrise	AHTS	1,242	417	667	833	167	8,100	300	750	375	250
2	BNI Aldebaran	AHTS	1,158	550	600	660	50	8,000	370	600	550	324
3	Naomi Sunbright	AHTS	1,163	494	647	699	140	10,000	390	500	530	480
4	Osam Manila	AHTS	1,250	350	370	370	42	5,500	290	400	300	300
5	Surf Mitra	AHTS	1,733	792	958	1,080	42	14,000	303	600	640	812
6	TSS Beata	AHTS	1,123	440	500	600	25	7,400	300	600	314	250
7	TSS Pioneer 4	AHTS	1,265	440	500	600	25	8,000	300	550	510	410
8	LCT Alfa Trans 2	LCT	1,459	167	186	N/A	15	4,000	608	482	334	100

Table 3.
Fleet Assignment Group List of CNOOC SES Ltd[18)]

k	Assignment	Distance (km)	Operation Time (hour)
1	KJ4 - Pabelokan - KJ4	175.16	14.82
2	Pabelokan - COSL221 - P. Excelcior - COSL222 - Pabelokan	76.11	12.64
3	Pabelokan - PTM - Lisa - COSL223 - Pabelokan	212.50	21.84
4	KJ4 - P.Exelcior-KJ4 (*direct route central*)	240.09	19.20
5	KJ4 - PTM - KJ4 (*direct route north*)	327.73	24.00
6	Towing	20	12.15
7	Assisting the drilling rig operation activities	15	1.01

Table 4 up to Table 6 below shows data for fuel consumption (Fkm), idle time (Ikm) and fuel consumption on standby (Gkm). Especially in Tables 4 and 5, data for vessels number 8 for assignments 2 to 7 are filled with large dummy data, which is 100,000. This is due to the fact that the operation, vessel number 8 or LCT, cannot dock to the barge and cannot carry out towing activities.

Table 4.
Fuel consumption for ship number **m** during cruising for assignment k (liter/km)[19)]

km		m							
		1	2	3	4	5	6	7	8
k	1	28.12	37.12	33.31	23.62	53.46	29.70	29.70	15.03
	2	28.12	37.12	33.31	23.62	53.46	29.70	29.70	100000
	3	28.12	37.12	33.31	23.62	53.46	29.70	29.70	100000
	4	28.12	37.12	33.31	23.62	53.46	29.70	29.70	100000
	5	28.12	37.12	33.31	23.62	53.46	29.70	29.70	100000
	6	365.60	363.80	355.31	218.01	558.86	310.48	310.48	100000
	7	28.12	37.12	33.31	23.62	53.46	29.70	29.70	100000

Table 5.
Vessel m *idle time* on assignment k (hour)[19)]

I_{km}		m							
		1	2	3	4	5	6	7	8
k	1	9.18	9.18	9.18	9.18	9.18	9.18	9.18	5.24
	2	11.36	11.36	11.36	11.36	11.36	11.36	11.36	100000
	3	2.16	2.16	2.16	2.16	2.16	2.16	2.16	100000
	4	4.80	4.80	4.80	4.80	4.80	4.80	4.80	100000
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100000
	6	11.85	11.85	11.85	11.85	11.85	11.85	11.85	100000
	7	22.99	22.99	22.99	22.99	22.99	22.99	22.99	100000

Table 6.
Fuel consumption for ship number m during standby on assignment k (liter/hr)[19)]

G_{km}		m							
		1	2	3	4	5	6	7	8
k	1	167	50	140	42	42	25	25	15
	2	167	50	140	42	42	25	25	15
	3	167	50	140	42	42	25	25	15
	4	167	50	140	42	42	25	25	15
	5	167	50	140	42	42	25	25	15
	6	167	50	140	42	42	25	25	15
	7	167	50	140	42	42	25	25	15

2. Integer Programming Model Formulation

The Integer Programming model formulation of the shipping fleet is directed at minimizing costs from fleet operations. The cost function is the sum of the total fixed costs, namely boat rental prices, and variable costs, namely the use of fuel which depends on the type of assignment or vessel activity.

From the analysis of operational data, objective functions can be formulated as can be seen in equation 8 below.

$$Total\ Cost = \sum_{m=1}^{M} R_m * S_m + \sum_{k=1}^{K}\sum_{m=1}^{M}\{(D_k * F_{km} + I_{km} * G_{km}) * P * L_{km}\} \quad (8)$$

The formulation in equation 8 is an assignment problem, where the decision to be taken is the placement of ships in the assignment, i.e. the assignments that will provide the lowest total operating costs.

Constraints based on the actual conditions of the CNOOC SES Ltd shipping fleet operations must be met by equation 8.

These constraints are as follows:

$$\sum_{k=1}^{K}\sum_{m=1}^{M} L_{km} \geq M \quad (9)$$

$$L_{km} \in [1,0] \quad (10)$$

$$\sum_{m=1}^{M} L_{1m} = 1 \quad (11)$$

$$\sum_{m=1}^{M} L_{2m} = 1 \quad (12)$$

$$\sum_{m=1}^{M} L_{3m} = 1 \quad (13)$$

$$\sum_{m=1}^{M} L_{4m} = 1 \quad (14)$$

$$\sum_{m=1}^{M} L_{5m} = 1 \quad (15)$$

$$\sum_{m=1}^{M} L_{6m} = 1 \quad (16)$$

$$\sum_{m=1}^{M} L_{7m} = 1 \quad (17)$$

$$\sum_{k=1}^{K} L_{k1} \leq 1 \quad (18)$$

$$\sum_{k=1}^{K} L_{k2} \leq 1 \quad (19)$$

$$\sum_{k=1}^{K} L_{k3} \leq 1 \quad (20)$$

$$\sum_{k=1}^{K} L_{k4} \leq 1 \quad (21)$$

$$\sum_{k=1}^{K} L_{k5} \leq 1 \quad (22)$$

$$\sum_{k=1}^{K} L_{k6} \leq 1 \quad (23)$$

$$\sum_{k=1}^{K} L_{k7} \leq 1 \quad (24)$$

$$\sum_{k=1}^{K} L_{k8} \leq 1 \quad (25)$$

$$\sum_{k=1}^{K} L_{k1} \leq 1 \quad (26)$$

Equation 9 shows that all assignments are served with M ships available in the fleet. Equation 10 states that L_{km} decision variables are binary variables 0 or 1. Minimum vessel requirements for each assignment are shown by equations 11 through equation 17. Whereas the condition that one ship can only be allocated to one assignment every day is shown by equation 18 through equation 26.

Resumes from constants for L_{km} variables, binary logic for use of ship m in assignment k, can be seen in Table 7 below.

Table 7.
Variable constant L_{km}, binary logic for use of ship **m** on assignment **k**[19)]

L_{km}		m							
		1	2	3	4	5	6	7	8
k	1	6,456	6,961	7,118	4,523	9,749	5,431	5,431	2,711
	2	4,034	3,394	4,124	2,275	4,546	2,544	2,544	9,111,095
	3	6,336	7,996	7,381	5,111	11,450	6,365	6,365	22,750,261
	4	7,551	9,152	8,669	5,873	13,036	7,250	7,250	25,509,041
	5	9,217	12,166	10,918	7,742	17,519	9,733	9,733	34,273,343
	6	9,287	7,868	8,763	4,858	11,675	6,506	6,506	3,500,000
	7	4,253	1,706	3,714	1,320	1,767	1,020	1,020	3,000,000

Assumptions in Modeling

In formulating the model for the CNOOC SES Ltd shipping fleet, the assumptions used are as follows:

1. All ships are assumed to be available and can be operated.
2. Weather variability is not considered in the model, weather conditions are assumed to be constant under normal conditions.
3. The cruising speed for all AHTS is assumed to be constant, referring to the company standard, which is 8 knots.
4. The cruising speed for LCT is assumed to be constant, which is 6 knots.
5. The towing speed for all AHTS is assumed to be constant, which is equal to 2 knots.
6. The loading and unloading time for each anchor point is assumed to be 1.5 hours.
7. The amount of cargo flow from each point is not used as input into the optimization equation formulation process, this is because the results of observations of material delivery data from January 2011 to the end of March 2013, the average material delivery from each point / node is still obtained below the capacity of each ship.
8. The main objective of the optimization process is the assignment problem to minimize fuel costs.

Optimization through Computer Simulation

Table 8.
Decision variables of Computer Simulations Results
Objective value: 108,536

Variable	Value (*)	Reduced Cost
R1	1	0
R2	1	0
R3	1	0
R4	1	0
R5	1	0
R6	1	0
R7	1	0
R8	1	0
L18	1	2,711
L22	1	11,394
L33	1	17,381
L47	1	19,250
L51	1	17,317
L64	1	10,641
L66	1	14,075
L75	1	15,767

(*) Decision variables with value = 0 are not displayed

Optimization solutions for problems that have been formulated are obtained with the help of LINGO version 8 optimization software. The solution to the optimization process with the LINGO version 8 software can be seen in Table 8 below.

Sensitivity Test

Sensitivity tests for integer programming problems are often more crucial than linear programming problems[12]. This is because a slight change in the coefficients in the boundaries can cause a relatively large change in the value of the optimal solution. Because of the extreme sensitivity level of linear integer programming problems to the coefficient of boundaries, practitioners usually recommend re-completing linear integer programs several times by making slight variations on the coefficients before choosing the optimal solution to apply[12].

For the case of the CNOOC SES Ltd shipping fleet, variations on the coefficient of boundaries will be carried out for equations 18 through equation 24, namely the limits that indicate the maximum number of assignments for each type of AHTS vessel. Variation is done by changing the maximum assignment limit to 2 for each ship, then simulating with Lingo 8.0 software, restarting for each variation of the limitation coefficient.

Ships that get a double assignment from the optimization of a variety of coefficients, will then be examined for the total operation time. If the total operating time turns out to be greater than 24 hours, then the solution is considered not feasible, if the opposite (≤ 24 hours), then the solution is feasible. Table 9 below shows the simulation results of the coefficient variations.

B. Discussion
Analysis of Optmization Results

The computer simulation results show that the optimum solution obtained is minimization of operating costs to the value of US $ 108,536 per day. This optimum solution is obtained through the ship assignment scenario as shown in Table 10 below.

By following the ship placement scenario as shown in Table 10, it is expected that there will be a decrease in fleet operating costs. This is because the ship placement scenario based on the assignment list in Table 10 is the configuration with the lowest fuel consumption.

As an alternative to the results of the optimization in Table 10, operating costs can be further reduced to US $ 102,475, according to the optimization results in the sensitivity test in Table 9. This decrease is achieved by applying the assignment configuration in Table 11.

In the configuration scheme in Table 11, AHTS BNI Aldebaran was given a dual assignment, namely to assist in the operation of drilling rigs and AHTS Surf Mitra was not operated. This scheme can be implemented, noting that the assignment to support the operation of drilling rigs can be temporarily abandoned (AHTS is not 24 hours standby for drilling rigs).

The current operating scheme at the CNOOC SES Ltd, the placement of ships on certain assignments has not considered the fuel consumption characteristics of each ship. Placement of ships to an assignment is carried out randomly without any studies for optimum operational scenarios.

In comparison, the average operating costs for the supplier's fleet at CNOOC SES Ltd are US $ 112,035.- per day. So, in ideal conditions according to the assumptions outlined above, the implementation of the operating scheme in Table 10 will provide operating cost savings of 3.12% per day.

Table 9.
Sensitivity Test Results through Variable Boundary Variations

Variable Constraint	Maximum Assignment	Total Operating Time per day (hour)	Objective Value (US$)	Assignment	*Feasible* (Yes/No)
Vessel-1	2	43	102,026	4 & 5	No
Vessel-2	2	14	102,475	2 & 7	Yes, if and only if there is no drilling activity
Vessel-3	2	39	105,044	1 & 5	No
Vessel-4	2	31	97,748	4 & 6	No
Vessel-5	2	1	108,536	7	The results are the same as the initial conditions
Vessel-6	2	25	101,025	2 & 6	No
Vessel-7	2	31	105,625	4 & 6	NO

Table 10.
Optimum Scenario for Ship Fleet Assignment at CNOOC SES Ltd

k	Assignments	Vessels / ships used
1	KJ4 - Pabelokan - KJ4	LCT Alfa Trans 2
2	Pabelokan - COSL221 - P. Excelcior - COSL222 - Pabelokan	BNI Aldebaran
3	Pabelokan - PTM - Lisa - COSL223 - Pabelokan	Naomi Sunbright
4	KJ4 - P.Exelcior-KJ4 (*direct route central*)	TSS Pioneer 4
5	KJ4 - PTM - KJ4 (*direct route north*)	Abigail Sunrise
6	*Towing*	Osam Manila & TSS Beata
7	Assisting the drilling rig operation activities	Surf Mitra

Table 11.
Optimum Scenario Alternative for Ship Fleet Assignment at CNOOC SES Ltd

k	Assignments	Vessels / ships used
1	KJ4 - Pabelokan - KJ4	LCT Alfa Trans 2
2	Pabelokan - COSL221 - P. Excelcior - COSL222 - Pabelokan	BNI Aldebaran
3	Pabelokan - PTM - Lisa - COSL223 - Pabelokan	Naomi Sunbright
4	KJ4 - P.Exelcior-KJ4 (*direct route central*)	TSS Pioneer 4
5	KJ4 - PTM - KJ4 (*direct route north*)	Abigail Sunrise
6	*Towing*	Osam Manila & TSS Beata
7	Assisting the drilling rig operation activities	BNI Aldebaran

The results of previous publications related to the use of integer programming to optimize ship operating costs in oil and gas offshore installations are still not many. Existing publications generally only discuss routing problems, such as publications that have been conducted by Fagerholt and Lindstad (2000), Aas et al (2007) and

Gribkovskaia et al (2007)[2). Previous research related to fleet design has also not many, one of which was carried out by Aas, Halskau and Wallace (2009) with the title of the role of supply vessels in offshore logistics[2). They only discussed the role of variables that influence the fleet design, there are no quantitative calculations. Seixas, et al (2016) have conducted research related to supply ships, but in terms of goods packaging problems[1).

However, the publication of the use of integer programming to optimize costs in other fields has been done quite a lot. Some examples include, the issue of daily fleet assignments to Turkish Airline which could reduce the minimum daily costs for fleet assignments to $ 732,872[20), and at PT XYZ its after-sales service process costs could be reduced around 12.14% and its process speed could be increased around 7.4%[21).

Strategy for Implementing the Ptimization Results

In order for the optimization results of the shipping fleet operation to be effectively implemented in the company CNOOC SES Ltd, it requires the involvement of the management as a party that fully supports the implementation of the optimization program. The management involvement is at a minimum at the managerial level of the Logistics and Marine Operations Department that in charge of the transportation section. The socialization of the optimization program to the transportation section also needs to be done, especially in the operational control section of the fleet.

Observation of the amount of operating costs during the implementation of the optimization program needs to be done to determine whether the optimization program has a positive impact or not on the company. Adjustments to the fleet model formulation need to be done if the results of the application do not have a positive impact in the form of reducing operating costs.

CONCLUSION

The current number of supply vessels operating in the CNOOC SES Ltd offshore area, with a configuration of 1 (one) LCT and 7 (seven) AHTS, is still sufficient for the minimum normal operational activities consisting of seven types of assignments. For the consistency of operations and ease of planning, fleet activities need to be clearly mapped so that the allocation of vessel resources to specific assignments can be determined at the beginning of operations. The results of the optimization in this research conclude that with ideal conditions in accordance with the assumptions outlined above, it will provide operating cost savings of 3.12% per day or equivalent to US$ 3,495.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the Head of the Master of Management Study Program, Faculty of Economics & Business, University Indonesia, and Master of Management FEB UI Library staff for the facilities provided in supporting this research. We also would like to say thank you to our fellow researchers at the Center for Materials Technology - BPPT, who already gave very valuabe suggestions so that this paper can be completed.

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