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The financial impact of fleet composition for offshore supply operation

Abstract

The main objective of the study is to minimize as much as possible of the total costs paid by offshore oil companies for their offshore supply operations through the optimal configuration of offshore supply vessels (choosing the number of vessels needed for supply operations - choosing the best depots for supply - the best economic paths for the selected vessels - reducing the total time required for the process of supplying the rigs with the necessary requirements) ... The results of the analysis highlighted the importance of offshore supply operations that may lead to a complete stoppage of production and the challenges associated with managing them. The most important obstacles facing offshore supply operations are costs related to supply operations. Further, the wastages, delays in supplying, and shortages in supply units.

In this context, the financial impact of the study is primarily focused on minimizing total costs incurred by offshore oil companies for their supply operations. By optimizing fleet composition, depot selection, and vessel routes through the use of a genetic algorithm, companies can reduce operational expenses, avoid costly idle time of drilling rigs, and mitigate expenses related to wastages, delays, and supply shortages. These financial improvements contribute to increased profitability and overall financial performance for offshore oil companies.

Keywords: Offshore Supply chain, vehicle routing problem, Fleet Composition and Routing, Genetic Algorithm, Financial Management

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الأثر المالي لتكوين الأسطول لعمليات التوريد البحرية

ملخص البحث

الهدف الرئيسي من الدراسة هو تقليل التكاليف الإجمالية التي تدفعها شركات النفط البحرية إلى أقصى حد ممكن لعمليات التوريد البحرية من خلال التكوين الأمثل لسفن الإمداد البحرية (اختيار عدد السفن اللازمة لعمليات التوريد - اختيار أفضل المستودعات للإمداد - أفضل المسارات الاقتصادية للسفن المختارة - تقليل الوقت الإجمالي اللازم لعملية تزويد الحفارات بالمتطلبات اللازمة) ... أبرزت نتائج التحليل أهمية عمليات الإمداد البحرية التي قد تؤدي إلى اكتمال توقف الإنتاج والتحديات المرتبطة بإدارتها. أهم العقبات التي تواجه عمليات التوريد البحرية هي التكاليف المتعلقة بعمليات التوريد. كذلك الهدر والتأخير في التوريد ونقص وحدات التوريد.

في هذا السياق ، يركز الأثر المالي للدراسة بشكل أساسي على تقليل إجمالي التكاليف التي تتكبدها شركات النفط الخارجية لعمليات التوريد الخاصة بها. من خلال تحسين تكوين الأسطول واختيار المستودع وطرق السفن من خلال استخدام خوارزمية جينية ، يمكن للشركات تقليل النفقات التشغيلية وتجنب وقت الخمول المكلف لمنصات الحفر وتخفيف النفقات المتعلقة بالهدر والتأخير ونقص الإمداد. تساهم هذه التحسينات المالية في زيادة الربحية والأداء المالي العام لشركات النفط البحرية.

الكلمات المفتاحية: سلسلة التوريد البحرية، مشكلة توجيه السيارة، تكوين الأسطول والتوجيه، الخوارزمية الجينية، الإدارة المالية.

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1. Introduction

The offshore oil and gas industry relies heavily on efficient supply operations to meet the demands of production and drilling installations deployed in offshore oil fields. Timely and adequate supply of materials, equipment, and services to these offshore facilities is crucial for maintaining smooth operations and maximizing financial returns. However, the complexities of the surrounding environment, high-scale demands, and various operational constraints pose significant challenges in ensuring a seamless supply process (Araújo et al., 2020).

Offshore supply services are typically conducted by fleets of offshore supply vessels, which navigate between onshore depots and offshore facilities. In practice, offshore oil and gas companies often lease these supply vessels from service companies under time charters. The efficient arrangement and management of these supply operations are the responsibilities of the charterer, the offshore oil and gas companies. Any improper or delayed supply can lead to substantial costs, such as idle time for drilling rigs, which can amount to several hundred thousand USD per day. Moreover, extended vessel leasing days and, in worst cases, the shutdown of installations due to lack of supplies, can significantly impact financial performance (Ismail et al., 2017).

The complexity of offshore supply operations in real-life scenarios necessitates the use of advanced optimization techniques to address the vehicle routing problem (VRP) effectively. In this regard, the specific problem under focus in this study is in the Suez Gulf, where two onshore depots provide different supplies to ten offshore facilities. Loading and unloading restrictions at both depots and rigs, maintenance requirements, safety considerations, and the need to mitigate operational risks further amplify the problem's level of complexity (Saunier et al., 2019).

The primary purpose of this study is to minimize the total costs borne by offshore oil companies for their offshore supply operations. By optimizing the configuration of offshore supply vessels, selecting the best depots for supply, and determining the most economical paths for these vessels, the study aims to reduce the overall time required for supplying the rigs with their necessary requirements.

Traditional manual planning of offshore supply operations, while performed by experienced logistic personnel, may not explore all possible solutions due to the numerous variables involved. Hence, optimization techniques, such as the genetic algorithm, are proposed as effective decision support tools to aid planners in their work (Monteiro et al., 2020).

This research delves into the application of the genetic algorithm to solve the offshore supply operations problem in the Suez Gulf. The study aims to propose an optimum fleet of supply vessels and their respective routes, while adhering to all relevant constraints, including the multi-commodity nature of the problem. Through this investigation, the financial implications of efficient offshore supply operations are expected to be revealed, including cost reductions, minimized idle time, and improved overall financial efficiency (Borchani et al., 2021).

In summary, this study seeks to shed light on the financial impact of optimizing fleet composition and offshore supply operations through the use of the genetic algorithm. By addressing the complexities and challenges of offshore logistics, the research aims to enhance financial performance and strategic decision-making for offshore oil and gas companies operating in the Egyptian context.

2. Research Objectives

At present, in EGYPT, little research has been conducted in this area. So, the objective is *determining the best combination of fleet composition for offshore supply operations* in which costs can be reduced to the minimum allowable, while satisfying the real-life constraints and supply demand

The optimization tool will be developed to find these points in this study:

1. Minimize total cost.

The main objective of the research lies in how to reduce the largest possible amount of the total costs that oil exploration companies in the seas pay to supply the drilling rigs with the necessary requirements to complete the drilling process.

2. Minimize total time.

minimizing the time required for the process of supplying the rigs with the necessary requirements, reducing the number of trips of the drilling supply ships, by preparing a pre-plan for all the requirements for the rigs during the project period, which in turn reduces the time and thus saves the total costs.

3. choosing the best economic paths.

Choosing the best economic paths for the rigs supply vessels to meet the required needs, which in turn reduces the time and this saves the total costs.

4. choosing the best onshore supply depot.

determine and choose the best onshore supply depot through which the supply will be made to offshore installations that are closer to the offshore installations, which in turn reduces the time and thus saves the total costs.

3. Literature Review

The literature review on supply vessel planning and related optimization problems reveals several innovative solution approaches and methodologies proposed by different researchers. (Kisialiou et al. 2018a) and (Kisialiou et al.2019) addressed the Periodic Supply Vessel Planning Problem (PSVPP) and the problem with uncertain demand using the Adaptive Large Neighbourhood Search (ALNS) heuristic and discrete-event simulation models. (De Bittencourt et al.2021) built a framework combining simulation and optimization for cargo assignment and fleet sizing in offshore logistics. (Cruz et al.2019) proposed a mathematical model and heuristic approach for the heterogeneous fleet-sizing problem of platform supply vessels (PSVs).

The Pickup and Delivery Problem (PDP) has been extensively studied, and researchers have proposed various metaheuristics and hybrid approaches to solve it. (Ben-Said et al.2022) developed a two-phase Pareto-local search based on decomposition for the Selective Pickup and Delivery Problem (SPDP). (Olgun et al.2021) introduced a hyper-heuristic detection algorithm (HH-ILS) for the Green Vehicle Routing Problem with Pickup and Delivery (G-VRPSPD).

In the context of multi-depots, researchers have focused on solving various vehicle routing and location-routing problems. (Voigt et al.2022) developed a hybrid adaptive large neighbourhood search for the Multi-Depot Vehicle Routing Problem (MDVRP). (Wu et al.2022) applied ALNS to solve the Multi-Allocation Hub Location Routing Problem (MAHLRP). (Liu et al.2014) used a hybrid genetic algorithm for the Multi-Depot Open Vehicle Routing Problem (MDOVRP).

Other studies have addressed issues related to multi-objective optimization, time-dependent demands, and green logistics. (Fardi et al.2019) studied a cooperative game theory algorithm for the Multi-Depot Multivehicle Robust Inventory Routing Problem (Co-RIRP). (Zabihian-Bisheh et al.2022) proposed evolutionary metaheuristics for the Multi-Depot Green Capacitated Location Routing Problem (MGCLRP) under uncertainty.

According to previous studies, on fleet composition for offshore supply operations has predominantly focused on tactical and strategic levels, leading to the development of efficient planning-support tools for the industry. However, a significant research gap exists at the operational level of supply vessel planning, where studies have yet to utilize the best combination of fleet composition from multi-depots as input to solution methods. This lack of attention has hindered the development of a simplified approach to reduce delivery costs for offshore installations, limiting practical and easy-to-implement solutions for decision-makers. Therefore, this study aims to address this gap by introducing a novel operational view of supply vessel planning, incorporating multi-depots, and providing a user-friendly approach for optimizing fleet composition and cost reduction in offshore supply operations.

The complexities further extend to pickup and delivery problems, where intricate constraints such as time windows and capacity limitations come into play. Here, the amalgamation of methodologies like simulated annealing and adaptive local search strategies has surfaced as a potent arsenal (Lalla-Ruiz et al., 2016; Li et al., 2016). These approaches deftly address the intricacies of real-world scenarios, accommodating various constraints and objectives.

In essence, this rich tapestry of research contributions underscores a collective commitment to advancing the efficiency, robustness, and cost-effectiveness of offshore supply chain management and associated optimization challenges (Christiansen et al., 2017; Norlund et al., 2015). By harnessing innovative solution techniques and leveraging interdisciplinary insights, these studies pave the way for informed decision-making in the ever-evolving landscape of offshore supply operations.

4. Problem Description

Figure 1 problem description

A mathematical model was developed to optimize fleet composition for offshore supply operations. A Genetic Algorithm is applied using software package, Evolutionary Solver in Excel 2019 to find the best combination of fleet composition for offshore supply operations. Figure 1 refers to the problem addressed in this study is to determine the optimal fleet composition for offshore supply operations, with the objective of minimizing costs while ensuring secure and dependable supply chains. The problem involves a tactical and operational planning horizon, divided into hours, with a fixed number of offshore installations, a variable number of platform supply vessels (PSVs), and two onshore bases. The demands are categorized as planned and unplanned, and they are transported using PSVs for planned normal demand only, while helicopter transport and unplanned demands are excluded from the model. The capacity of both PSVs and offshore installations is limited. The PSVs sail various routes to visit offshore facilities, and the routing of PSVs must be determined, considering time constraints and visiting multiple offshore facilities on a single route. The vessels have time limits for their voyages, and no waiting times or slack are allowed in the sailing schedule. Several assumptions are made to simplify the problem, including constant availability of bases and facilities, no queuing or shortage of equipment, and personnel transport via helicopters not being considered. Overall, the problem presents a complex optimization challenge to determine the best fleet composition for offshore supply operations with minimized costs. According to (Lundgren, Rönnqvist, & Värbrand, 2010) optimization is an interesting decision support tool and it can be a useful technique for analyzing the cost associated with diverse optimizing problems.

5. Mathematical Model Formulation

The offshore supply vessel planning optimization problem is a special kind of vehicle routing problem, which can be abstracted to be a combination of the bin-packing problem (BPP), for optimizing the composition of the supply fleet and the vehicle routing problem (or Travelling salesman problem TSP, if the number of vehicles needed is one) with simultaneous pick-up and delivery (VRPSPD), for optimizing supply routing planning. to solve this problem used four mathematical models as follows:

5.1 Mathematical model for Bin-packing problem (BPP)

According to the Mathematical Model in Genetic Algorithms and Engineering Optimization, (Mitsuo Gen, 2000) the mathematical model formulation was developed to minimize the number of vessels needed as follows:

Set:

n: the number of cargo units a: the area of one cargo unit

cap: the loading capability of one vessel (the area of deck)

V: the number of vessels used

Minimize:

$$V = \sum_{j=1}^{n} y_j \qquad (1)$$

Subject to: $$\sum_{i=1}^{n} a_i x_{ij} \le \text{cap} \times y_j\,, \quad \forall i \in N = \{1,2,\cdots,n\} \qquad (2)$$

$$y_j = 0 \text{ or} 1, \qquad \forall\, i \in \mathrm{N} \qquad (3)$$

$$x_{ij} = 0 \text{ or } 1, \qquad \forall i\,, j \in \mathrm{N} \qquad (4)$$

Remark:

$$xij = \begin{cases} 1, & \text{means that packing unit } i \text{ into vessel } j \\ 0, & \text{otherwise} \end{cases}$$

$$yi = \begin{cases} 1, & \text{means that vessel } j \text{ de used} \\ 0, & \text{otherwise} \end{cases}$$

The constraint requires that the total area of the cargo unit that is packed into vessel j must not exceed the capacity of the vessel j.

5.2 Mathematical model for the vehicle routing problem with simultaneous pick-up and delivery (VRPSPD)

Based on the mathematical model developed by (Toth et al., 2014), a mathematical model is built to minimizing the total sailed distance by a fleet of supply vessels as follows:

Sets:

V: set of supply vessels used in one voyage

I: set of offshore installations.

N: set of all nodes including depot.

Parameters:

v: number of vessels in one voyage, v∈V

n: number of nodes, n∈N; n=0 denotes the depot.

d: supply vessel sailing distance.

cap: vessel carrying capacity.

d_{ij}: distance between nodes i and j   i, j ∈ N, I ≠ j.

d_i: cargo amount demanded by installation i, i ∈ I.

p_i: cargo amount picked up from installation i, i ∈ I.

Decision Variables:

D_{ijv}: The remaining cargo to be delivered by the v-th vehicle when departing from node i to j.

p_{ijv} : The cumulative cargo picked up by the v-th vehicle when departing from node i to j .

u_{ijv}: The cargo of the v-th vehicle when departing from node i to j

x_{ijv}: Binary decision variable that indicates whether the v-th vehicle travels from i to j.

x_{ijv} = 1, if the vehicle travels directly from i to j = 0, otherwise

Minimize:

$$\sum_{i=0}^{i=N}\sum_{j=0}^{j=N}\sum_{v=1}^{v=V} d_{ij}\ x_{ijv} \tag{1}$$

Subject to:

$$\sum_{j=1}^{j=N}\sum_{v=1}^{v=V} x_{ijv} = \sum_{j=1}^{j=N}\sum_{v=1}^{v=V} x_{jiv} = V \qquad i = 0, j \in N, v \in V \tag{2}$$

$$\sum_{i=0}^{i=N}\sum_{v=1}^{v=V} x_{ijv} = 1 \qquad \forall i \in N, v \in V \tag{3}$$

$$\sum_{j=0}^{j=N}\sum_{v=1}^{v=V} x_{ijv} = 1 \qquad \forall j \in N, v \in V \tag{4}$$

$$\sum_{j\in N} x_{ijv} = \sum_{j\in N} x_{jiv} = 1 \qquad i = 0, j \in N, v \in V \qquad (5)$$

$$\sum_{j=1}^{j=N} D_{0jv} = \sum_{i=0}^{i=N}\sum_{j=0}^{j=N} x_{ijv} d_i \qquad \forall v \in V, i \neq j$$

$$\sum_{i=1}^{i=N} P_{i0v} = \sum_{i=0}^{i=N}\sum_{j=0}^{j=N} x_{ijv} p_i \qquad \forall v \in V, i \neq j$$

(7)

$$\sum_{j=1}^{j=N} D_{0jv} \leq cap \qquad \forall i, j \in N, v \in V$$

(8)

$$\sum_{i=1}^{i=N} P_{i0v} \leq cap \qquad \forall i, j \in N, v \in V$$

(9)

$$u_{ijv} \leq x_{ijv} \times cap \qquad (10)$$

$$D_{ijv} \geq 0 \qquad P_{ijv} \geq 0 \qquad (11)$$

$$u_{iv} - u_{jv} + cap \times x_{ijv} \leq C - d_j \qquad \forall i, j \in N, v \in V, i \neq j$$

$$d_i \leq u_{iv} \leq cap \qquad (12)$$

$$x_{ijv} \in \{0,1\} \text{ and integer} \qquad \forall i, j \in N \qquad (13)$$

(6)

Th objective function (1) minimizes the total sailed distance by a fleet of supply vessels.

Constraint (2) ensures that the number of the vehicles which start from the depot and go back to depot is V.

Constraints (3), (4) explain that each customer can only be served by one vehicle. Further, constraint (5) means all the vehicles which start from the depot go back to the same depot.

Equation (6) means that the initial loading cargo amount at the depot equal to the sum of the cargo amount demanded by all installations.

Equation (7) means that the cumulative load picked up by the v-th vehicle when departing from node i to depot.

Constraints (8) and (9) are transit load constraints.

Constraint (10) ensures that no matter where the vehicle is, the load cannot exceed the vehicle's capacity.

Constraint (11) maintains non-negativity of $Dijv$ and $Pijv$. Constraint

(12) is the subtour elimination constrains, e.g., when $xijv = 1$, $ujv \geq uiv + dj$.

$xijv$ is a binary decision variable as in (13).

5.3 Mathematical model for the traveling salesman problem (TSP)

This part of the mathematical model aims to find the shortest supply routes for the selected ships by solving the vehicle routing problem (VRP) (each vessel separately). (i.e., the vehicle routing problem (VRP) is divided into a group of traveling salesman problems (TSP)), each selected vessel has its own traveling salesman problem so as to find its own shortest supply route.

Minimize:

$$\sum_{i=0}^{i=N}\sum_{j=0}^{j=N} dij\,xij \qquad (1)$$

subject:

$$\sum_{i=0}^{i=N} x_{ij} = 1 \qquad \forall i \in N \qquad (2)$$

$$\sum_{j=0}^{j=N} x_{ij} = 1 \qquad \forall j \in N \qquad (3)$$

$$\sum_{i=0}^{i=N} \sum_{j=0}^{j=N} x_{ij} \leq |S| - 1, \qquad \forall S \in N, 2 \leq |S| \leq n - 2 \qquad (4)$$

$$x_{ijv} \in \{0,1\} \text{ and integer} \qquad \forall i, j \in N \qquad (5)$$

Remark:

$$xij = \begin{cases} 1, & \text{means the line between customer i to j is on the shortest route} \\ 0, & \text{otherwise} \end{cases}$$

The constraints (2), (3) represent that each customer can only be served once. Constraint (4) is the sub-tour elimination constraints.

5.4 Mathematical model for Minimize total cost.

In the fourth and final part of the mathematical model, the goal is to find the minimum cost of chartering ships that will be used to deliver and pick up orders for different installations,

Set:

the total charter cost: C

the vessel i charter rate: r_i

$$C = \sum_{j=1}^{n} r_i y_j \qquad (1)$$

Minimize:

Subject to:

$$\sum_{i=1}^{n} a_i x_{ij} \leq \text{cap} \times y_j , \quad \forall i \in N = \{1,2,\cdots,n\} \tag{2}$$

$$y_j = 0 \text{ or } 1, \qquad \forall\, i \in \text{N} \tag{3}$$

$$x_{ij} = 0 \text{ or } 1, \qquad \forall i\,, j \in \text{N} \tag{4}$$

Remark:

$$xij = \begin{cases} 1, & \text{means that packing unit } i \text{ into vessel } j \\ 0, & \text{otherwise} \end{cases}$$

$$yj = \begin{cases} 1, & \text{means that vessel } j \text{ be used} \\ 0, & \text{otherwise} \end{cases}$$

The constraint requires that the total area of the cargo unit that is packed into vessel j must not exceed the capacity of the vessel j.

6. Offshore Supply Operation Case Study

To evaluate the performance of offshore supply operations, the study studied an exploration company for offshore oil and gas in the Suez Gulf. This company has two onshore depots, ten offshore installations, and a number of supply vessels. Table 1 shows the distance between the first depot to ten offshore, Table 2 shows the distance between the second depot to ten offshore, Table 3 shows the demanded cargo volume (pickups and deliveries demand) by the offshore installations (1-10) in one typical supply voyage, Table 4 shows deck loading area with charter rate of available platform supply vessels (PSV), and Table 5 shows fuel consumption of "Metric Ton Fuel Oil" for each types vessel.

Table 1: Distance matrix of the 10 installations serviced by first depot

Distance (n mile)	depot	1	2	3	4	5	6	7	8	9	10
depot	0	17	14	40	55	45	30	25	15	50	55
Installation 1	17	0	46	48	49	40	38	43	45	40	35
Installation 2	14	46	0	5	12	7	10	13	15	18	20
Installation 3	40	48	5	0	6	15	23	17	12	21	16
Installation 4	55	49	12	6	0	35	47	30	42	51	39
Installation 5	45	40	7	15	35	0	36	17	22	43	51
Installation 6	30	38	10	23	47	36	0	25	29	27	41
Installation 7	25	43	13	17	30	17	25	0	51	37	20
Installation 8	15	45	15	12	42	22	29	51	0	33	31
Installation 9	50	40	18	21	51	43	27	37	33	0	22
Installation 10	55	35	20	16	39	51	41	20	31	22	0

Table 2: Distance matrix of the 10 installations serviced by second depot

Installation	1	2	3	4	5	6	7	8	9	10	
Cargo (unit)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**total**
Area (m^2) /delivery	85	72	68	57	74	53	83	85	92	90	759
Area (m^2) /pick- up	45	35	53	48	37	25	53	47	50	72	465

Table 3: Cargo demanded by the 1–10 installations in one supply planning voyage

Vessel available for charter	A	B	C	D	E	F	G	H	I	J	K
Deck loading area (m^2)	600	500	480	450	450	435	435	420	420	380	380
Charter rate (1000$/day)	13	11	10	9	9	8	8	7	7	6	6

Table 4: Deck loading area and charter rate of available platform supply vessels (PSV)

Distance (n mile)	depot	1	2	3	4	5	6	7	8	9	10
depot	0	73	51	35	50	40	7	18	45	31	30
Installation 1	73	0	23	24	25	32	63	50	44	52	50
Installation 2	51	23	0	8	10	25	40	27	36	32	30
Installation 3	35	24	8	0	12	11	32	23	27	30	25
Installation 4	50	25	10	12	0	13	41	29	30	28	26
Installation 5	40	32	25	11	13	0	31	18	40	26	27
Installation 6	7	63	40	32	41	31	0	8	43	26	24
Installation 7	18	50	27	23	29	18	8	0	28	22	22
Installation 8	45	44	36	27	30	40	43	28	0	33	17
Installation 9	31	52	32	30	28	26	26	22	33	0	21
Installation 10	30	50	30	25	26	27	24	22	17	21	0

7. Result & Discussion

7.1 Part1FleetCompositionforOffshoreSupply Operation

A mathematical model consisting of four parts was used: the first part explains how to reduce the number of vessels used using the mathematical model of the Bin Packing problem (BPP), while the second part of the model shows how to reduce the total sailing distances of the selected ships through the mathematical model of the vehicle steering problem (VRP). the third part demonstrates finding the supply shortest route to selected vessels via the traveling salesman problem (TSP) mathematical model, and finally, the fourth part demonstrates the mathematical model of total cost minimization.

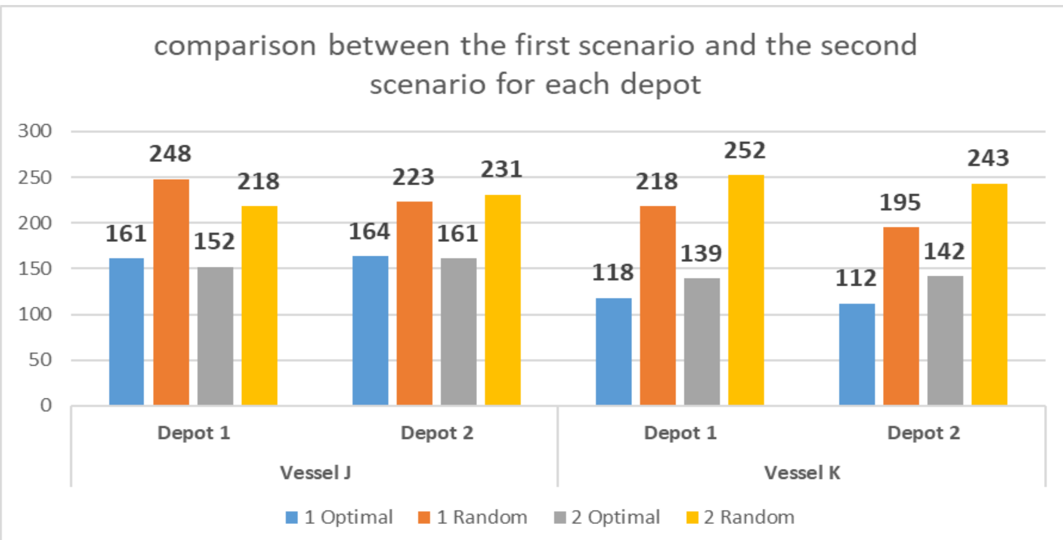

Figure 2: comparison between the first scenario and the second scenario for each depot

The model was solved using software (Microsoft Excel 2019 Evolutionary Solver) to determine the best combination of fleet composition for offshore supply operations in which costs can be reduced to the minimum allowable while satisfying real-life constraints and supply demands. The optimum solution returned is:

- 2 vessels were identified to serve 10 installations.
- The total cost of renting the identified vessels is $1,2000 /day, which is the type with a tonnage of 380 m2, Speed - Average/ Fuel Consumption "MT F.O" 10 knots /6/24 H, and Speed- Maximum / Fuel Consumption "MT F.O" 13 knots /7/24 H.
- There are 2 different scenarios of the optimal composition of the supply fleet in this supply cycle and to the scenarios two different solutions (optimal solution – random solution): for Vessels J, and K. Figure 2
  - Their service customers are listed below: (first scenario, optimal solution)
  - ➢ Vessel J: services installations 1, 2, 4, 5, 9
  - ➢ Vessel K: services installations 3, 6, 7, 8, 10
  - Their service customers are listed below: (second scenario)
  - ➢ Vessel J: services installations 2, 4, 5, 8, 9
  - ➢ Vessel K: services installations 1, 3, 6, 7, 10
- The first scenario was chosen because it is the optimal solution that reduces the total sailing distance as much as possible and thus reduces costs under the constraints imposed.
- the best combination of fleet composition for offshore supply operations in which costs can be reduced to the minimum allowable while achieving the highest degree of commitment in providing the requirements of the various installations. It means which vessel will serve the installations and from which depots they will be served, and what is the best sequence for visiting the installations.

- vessel J: serve installations (depot 1) 1, 2, 4, 5, 9 (depot 1) with a distance of 161.

- vessel K: serve installations (depot 2) 3, 6, 7, 8, 10 (depot 2) with a distance of 112.
- The total distance will be 273 miles.

- The amount of fuel consumption for the vessels selected to serve the 10 installations was 6805 liters with Speed- Maximum / Fuel Consumption “MT F.O” 13 knots /7/ 24 H.

  The time taken for the selected vessels to serve the 10 installations 21 H.

Table 5: percentage of optimization offshore supply operation

The optimal solution for the first scenario for each depot for the best combination of fleet composition for offshore supply operations									The random solution for the first scenario for each depot for the best combination of fleet composition for offshore supply operations								
Vessel	Supply Route	Depot 1	Total distance (n mile)	Total distance (n mile)	Depot 2	Total distance (n mile)	Total distance (n mile)	Total distance (n mile)	Supply Route	Depot 1	Total distance (n mile)	Total distance (n mile)	Depot 2	Total distance (n mile)	Total distance (n mile)	Total distance (n mile)	percentage of optimization
		Visit Sequence			Visit Sequence					Visit Sequence			Visit Sequence				
Vessel J	Optimal	depot-2-4-5-9-1-depot	161	279	depot-5-4-1-2-9-depot	164	276	-	Random	depot-9-4-1-2-5-depot	248	466	depot-4-2-9-5-1-depot	223	418	-	40%
Vessel K	Optimal	depot-6-7-10-3-8-depot	118		depot-10-8-3-7-6-depot	112			Random	depot-10-7-8-6-3-depot	218		depot-10-7-3-6-8-depot	195			33.9%
Vessel J	Optimal	depot-2-4-5-9-1-depot	161	161	-	-	112	273	Random	depot-9-4-1-2-5-depot	248	248	-	-	195	443	38.3%
Vessel K	-	-			depot-10-8-3-7-6-depot	112			-	-			depot-10-7-3-6-8-depot	195			
Vessel J	-	-	-	118	depot-5-4-1-2-9-depot	164	164	282	-	-	-	218	depot-4-2-9-5-1-depot	223	223	441	36%
Vessel K	Optimal	depot-6-7-10-3-8-depot	118		-	-			Random	depot-10-7-8-6-3-depot	218		-	-			

The objective of this study is to determine the best combination of fleet composition for offshore supply operations in which costs can be reduced to the minimum allowable while achieving the highest degree of commitment in providing the requirements of the various installations. it means which vessel will serve the installations and from which depots they will be served, and what is the best sequence for visiting the installations.

- vessel J: serve installations (depot 1) 1, 2, 4, 5, 9 (depot 1) with a distance of 161.
- vessel K: serve installations (depot 2) 3, 6, 7, 8, 10 (depot 2) with a distance of 112.

The total distance will be 273 miles.

the results of Table 5 show the percentage of optimizing offshore supply operations in this study as shown:

- The total route sailing distance (optimal solution) for the two vessels (J – K) from the depot 1 is better than the total path sailing distance (the random solution) for the two vessels (J – K) from the depot 1 by a ratio 40%
- The total route sailing distance (optimal solution) for the two vessels (J – K) from the depot 2 is better than the total path sailing distance (the random solution) for the two vessels (J – K) from the depot 1 by a ratio 33.9%
- The total route sailing distance (optimal solution) for vessel (J) from the depot 1 and vessel (K) from the depot 2 is better than the total route sailing distance (random solution) for vessel (J) from the depot 1 and vessel (K) from the depot 2 by a ratio 38.3%
- The total route sailing distance (optimal solution) for vessel (K) from the depot 1 and vessel (J) from the depot 2 is better than the total route sailing distance (random solution) for vessel (K) from the depot 1 and vessel (J) from the depot 2 by a ratio 36%

Although the highest improvement rate is for the first route with a percentage of 40%, this route is not the best route that can provide the required service and achieve the objective of the research. but the best route that can perform the required service and achieve the objective of the research (optimal solution) is the vessel route (J) from depot 1 to serve installations 2,4,5,9 and 1 with a distance of 161 miles, and the vessel route (K) from depot 2 to serve installations 10,8,3,7 and 6 with a distance of 112 miles, for a total distance of 273 miles. The best compared to the shortest sailing distance of the shortest random route (random solution) is the vessel route (J) from depot 2 to serve installations 4, 2, 9, 5, and 1 with a distance of 223 miles, and the vessel route (K) from depot 2 to serve installations 10, 7, 3, 6, and 8 with a distance of 195 miles with a total distance of 418 miles by a ratio of 34.6%.

7.2 Part 2 Financial Impact

This part shows the calculation of costs and time for fleet composition based on data of fuel consumption and time for each vessel in the Table 6, three equations were used: the first equation was used to calculate the time duration for the route in hours, the second equation was used to calculate the fuel consumption for the route in tons, and the third equation was used to convert tons of fuel consumption to liters.

$$T = \frac{D}{V} \qquad (1)$$

$$C = \frac{T}{24} \times F \qquad (2)$$

$$C_L = C \times \frac{1000}{\rho} \qquad (3)$$

T is the elapsed time in hours

D is the distance in kilometers

V is the speed in knots

C is the fuel consumption for covering the distance in tons

F is the fuel consumption per day in tons

CL is the fuel consumption in liters.

P is the density of liter in kilograms

According to Economic and Social Commission the Heavy fuel density (HFO) is (0.90)

Table 6: Fuel Consumption Data for the Ships & Boats AHTS

Types of vessels	Type 1		Type 2			Type 3				Type 4	
Vessel available for charter	A	B	C	D	E	F	G	H	I	J	K
Deck loading area (m^2)	600	500	480	450	450	435	435	420	420	380	380
Speed - Average/ Fuel Consumption "MT F.O"	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H	10 knots / 6 / 24 H
Speed- Maximum / Fuel Consumption "MT F.O"	13 knots / 11 / 24 H	13 knots / 11 / 24 H	12.5 knots / 11 / 24 H	12.5 knots / 11 / 24 H	12.5 knots / 11 / 24 H	12 knots / 7 / 24 H	12 knots / 7 / 24 H	12 knots / 7 / 24 H	12 knots / 7 / 24 H	13 knots / 7 / 24 H	13 knots / 7 / 24 H

Table 7: optimal solution for the first scenario for each depot

The optimal solution for the first scenario for each depot for the best combination of fleet composition for offshore supply operations								
Vessel	Supply Route	Depot 1	Total distance (n mile)	Total distance (n mile)	Depot 2	Total distance (n mile)	Total distance (n mile)	Total distance (n mile)
		Visit Sequence			Visit Sequence			
Vessel J	Optimal	depot-2-4-5-9-1-depot	161	279	depot-5-4-1-2-9-depot	164	276	--
Vessel K	Optimal	depot-6-7-10-3-8-depot	118		depot-10-8-3-7-6-depot	112		
Vessel J	Optimal	depot-2-4-5-9-1-depot	161	161	--	--	112	273
Vessel K	--	--			depot-10-8-3-7-6-depot	112		
Vessel J	--	--	--	118	depot-5-4-1-2-9-depot	164	164	282
Vessel K	Optimal	depot-6-7-10-3-8-depot	118		--	--		

Based on the data shown in the Table7 and extracted from the first part of the fleet composition, shows that there are 4 types of fleet composition for offshore supply operations (first scenario - optimal solution)

- The total route sailing distance (optimal solution) for the two vessels (J – K) from depot 1 is 279 miles.
- The total route sailing distance (optimal solution) for the two vessels (J – K) from depot 2 is 276 miles.
- The total route sailing distance (optimal solution) for vessel (J) from depot 1 and vessel (K) from depot 2 is 273 miles.
- The total route sailing distance (optimal solution) for vessel (K) from depot 1 and vessel (J) from depot 2 is 282 miles.

Figure 3: **matrix of total distance sailing and fuel consumption**

Figure 3 shows four cases of the relationship matrix between total distance sailing and fuel consumption for each type of fleet composition for offshore supply operations (first scenario - optimal solution):

1. (Low Consumption – Low Total Distance) The total route sailing distance (optimal solution) for vessel (J) from depot 1 and vessel (K) from depot 2 is 273 miles, and total fuel consumption 6805 Liter.

2. (High Consumption – High Total Distance) The total route sailing distance (optimal solution) for vessel (K) from depot 1 and vessel (J) from depot 2 is 282 miles, and total fuel consumption 7032 liter.

3. (High Consumption – Low Total Distance) The total route sailing distance (optimal solution) for the two vessels (J– K) from depot 1 is 279 miles, and total fuel consumption 6966 Liter.

4. (Low Consumption – High Total Distance) The total route sailing distance (optimal solution) for the two vessels (J– K) from depot 2 is 276 miles, and total fuel consumption 6870 Liter.

Figure 4: matrix of total distance sailing and total time sailing

Figure 4 shows four cases of the relationship matrix between total distance sailing and total time sailing for each type of fleet composition for offshore supply operations (first scenario – optimal solution):

1. (Low Consumption – Low Total Distance) The total route sailing distance (optimal solution) for vessel (J) from depot 1 and vessel (K) from depot 2 is 273 miles, and total time sailing 21 Hours.
2. (High Consumption – High Total Distance) The total route sailing distance (optimal solution) for vessel (K) from depot 1 and vessel (J) from depot 2 is 282 miles, and total time sailing 21.7 Hours.
3. (High Consumption – Low Total Distance) The total route sailing distance (optimal solution) for the two vessels (J – K) from depot 1 is 279 miles, and total time sailing 21.2 Hours.
4. (Low Consumption – High Total Distance) The total route sailing distance (optimal solution) for the two vessels (J – K) from depot 2 is 276 miles, and total time sailing 21.5 Hours.

8. Conclusion

This study tackled the challenge of optimizing offshore supply operations for Suez Gulf's oil and gas companies. Using a comprehensive approach that combines mathematical modeling and real-world data, the study aimed to cut costs, enhance efficiency, and address operational challenges. The study showcased the substantial impact of fleet composition and routing decisions on financial performance. By applying advanced optimization techniques, including Genetic Algorithms, the study successfully determined an optimal fleet mix that minimizes costs while meeting practical constraints and demand. This promises significant cost savings, lower fuel usage, and better overall efficiency, potentially revolutionizing offshore supply operations for improved profitability. The study addresses a gap in supply vessel planning, introducing a new method involving multiple depots and optimization. This provides decision-makers with a valuable tool for navigating complex offshore logistics effectively. Significantly, the study insights extend beyond the Suez Gulf, offering an adaptable framework for other offshore regions. As the industry seeks operational excellence, optimizing supply operations remains pivotal for sustainability and success.

In conclusion, the study highlights the importance of strategic decision-making in offshore supply operations and demonstrates the benefits of advanced optimization. By boosting efficiency, cutting costs, and enhancing financial performance, the study contributes to advancing offshore oil and gas logistics.

The study offers valuable recommendations for future research and practitioners in financial impact optimizing fleet composition for offshore supply operations. Future research should explore uncertainty impacts through techniques like stochastic modeling, study vessel characteristics' influence, and integrate sustainability measures such as alternative fuels and eco-friendly designs. Practitioners are advised to analyze supply needs comprehensively, leverage data-driven decision-making, collaborate with stakeholders, embrace emerging technologies, evaluate hybrid fleets, prioritize sustainability, ensure safety and compliance, and remain adaptable to changing conditions. These insights provide a comprehensive guide for enhancing operational efficiency, cost-effectiveness, and sustainability in offshore supply operations.

References

Araújo, L. V. S., Lisboa, J. V. G., & Cunha, C. B. (2020). Optimization model for offshore supply vessels and helicopter routing for oil and gas platforms. Computers & Industrial Engineering, 148, 106692.

Ben-Said, A., Moukrim, A., Guibadj, R. N., & Verny, J. (2022). Using decomposition-based multi-objective algorithm to solve Selective Pickup and Delivery Problems with Time Windows. Computers and Operations Research, 145. https://doi.org/10.1016/j.cor.2022.105867

Borchani, S., Jarboui, B., & Hanafi, S. (2021). A three-phase hybrid algorithm for the multi-objective berth allocation problem with time windows and mode of transportation constraints. *Journal of Computational Science,* 54, 101328.

Christiansen, M., et al. (2017). Solving fuel supply vessel route and scheduling problems. *European Journal of Operational Research,* 257(3), 845-858.

Cruz, R., Bergsten Mendes, A., Bahiense, L., & Wu, Y. (2019). Integrating berth allocation decisions in a fleet composition and periodic routing problem of platform supply vessels. *European Journal of Operational Research*, 275(1), 334–346. https://doi.org/10.1016/j.ejor.2018.11.030

de Bittencourt, G. C., Seimetz Chagas, R. D., Silva, V. A., Peres Vianna, I. G., Longhi, R. P., Ribas, P. C., & Ferreira Filho, V. J. M. (2021). A solution framework for the integrated problem of cargo assignment, fleet sizing, and delivery planning in offshore logistics. Computers and Industrial Engineering, 161. https://doi.org/10.1016/j.cie.2021.107653

Fardi, K., Jafarzadeh Ghoushchi, S., & Hafezalkotob, A. (2019). An extended robust approach for a cooperative inventory routing problem. Expert Systems with Applications, 116, 310–327.

https://doi.org/10.1016/j.eswa.2018.09.002

http://ships-boats.com/wp-content/uploads/2021/08/SEA-CHAMPION.pdf

https://archive.unescwa.org/sd-glossary/heavy-fuel-oil-residual

Ismail, M., Mahmoud, M. A., & Rahim, N. A. (2017). Scheduling offshore oil production and transportation operations: A review and analysis. Maritime Economics & Logistics, 19(4), 593-619.

Kisialiou, Y., Gribkovskaia, I., & Laporte, G. (2018a). Robust supply vessel routing and scheduling. Transportation Research Part C: Emerging Technologies, 90, 366–378. https://doi.org/10.1016/j.trc.2018.03.012

Kisialiou, Y., Gribkovskaia, I., & Laporte, G. (2019). Supply vessel routing and scheduling under uncertain demand. Transportation Research Part C: Emerging Technologies, 104, 305–316.

https://doi.org/10.1016/j.trc.2019.04.011

Lalla-Ruiz, E., et al. (2016). Adaptive large neighborhood search with reoptimization for the pickup and delivery problem with time windows. Computers & Operations Research, 65, 140-152.

Li, Y., et al. (2016). Adaptive large neighborhood search for the time-dependent profitable pickup and delivery problem with time windows. *European Journal of Operational Research*, 248(3), 791-802.

Liu, R., Jiang, Z., & Geng, N. (2014). A hybrid genetic algorithm for the multi-depot open vehicle routing problem. OR Spectrum, 36(2), 401–421. https://doi.org/10.1007/s00291-012-0289-0

Lundgren, J., Rönnqvist, M., & Värbrand, P. (2010). Optimization. Lund: Studentlitteratur.

Mitsuo Gen, R. C. (2000). Genetic Algorithms and Engineering Optimization (Engineering Design and Automation) (Mitsuo Gen, Runwei Cheng) (z-lib.org).

Monteiro, C., Monteiro, V., & Fontes, D. (2020). Multi-objective optimization for a real-world offshore vessel routing problem considering costs and environmental impacts. *Journal of Cleaner Production*, 252, 119882

Norlund, E., et al. (2015). A simulation–optimization approach for tactical supply vessel planning. *European Journal of Operational Research,* 247(3), 804-816.

Olgun, B., Koç, Ç., & Altıparmak, F. (2021). A hyper heuristic for the green vehicle routing problem with simultaneous pickup and delivery. Computers and Industrial Engineering, 153.

https://doi.org/10.1016/j.cie.2020.107010

Saunier, N., Fagerholt, K., & Gribkovskaia, I. (2019). A review of offshore logistics. *European Journal of Operational Research,* 278(2), 367-382.

Toth, P., Vigo, D., & Society for Industrial and Applied Mathematics. (2014). Vehicle routing: problems, methods, and applications.

Voigt, S., Frank, M., Fontaine, P., & Kuhn, H. (2022). Hybrid adaptive large neighborhood search for vehicle routing problems with depot location decisions. Computers and Operations Research, 146.

https://doi.org/10.1016/j.cor.2022.105856

Wu, Y., Qureshi, A. G., & Yamada, T. (2022). Adaptive large neighborhood decomposition search algorithm for multi-allocation hub location routing problem. *European Journal of Operational Research,* 302(3), 1113–1127. https://doi.org/10.1016/j.ejor.2022.02.002

Zabihian-Bisheh, A., Pourrezaie-Khaligh, P., Farrokhi-Asl, H., W.T. Lim, S. F., Rabbani, M., & Khamechian, M. (2022). Multi-depot green capacitated location routing problem considering uncertainty and in-facility queuing. Cleaner Waste Systems, 2, 100011.

https://doi.org/10.1016/j.clwas.2022.100011