Optimization of Marine Debris Collection Routing for Solar and Diesel Hybrid Power Vessels

Ling Tao, Gang Duan, Yuejiao Wei, Xiaohui Chen, Tao Fan

1School of Traffic and Transportation, Lanzhou Jiaotong University, Lanzhou, Gansu, 730070, China

Abstract: With the increase of marine debris and the serious destruction of the ecological environment, marine debris collection has become an urgent task facing us. In this paper, the logistics network is used to optimize the routing of marine debris collection vessels. In order to reduce carbon emissions, we choose to use new energy waste collection vessels which have solar and diesel hybrid power. The objective of this paper is to minimize the total cost. The constraints include time window, vessel capacity and carbon emissions, which are solved by large-scale neighborhood search algorithm. Taking the East China Sea as an example, the results show that the total cost and total time can be saved by 20.58% and 17.43% respectively by choosing the best debris collection time. Under different environmental conditions, when the photovoltaic penetration of solar hybrid vessel reaches 75%, the cost can be saved by 22.14%, and the carbon emission can be reduced by 74.7%. Through the analysis of different types of vessels, it is found that 11.85% of the cost can be saved by selecting the best vessel type.

1. Introduction
With the rapid development of coastal economy, human activities are becoming more frequent, marine debris is increasing, and the marine environment is deteriorating[1]. Marine debris is a kind of persistent, man-made or processed solid debris in marine and coastal environment, which has the characteristics of long-term, complexity and fluidity[2]. Marine debris has seriously affected the health of the entire marine ecosystem, and its negative impact on marine life and humans cannot be ignored. In recent years, people have begun to realize the harmfulness of marine debris and have adopted a series of prevention and control measures. Many conventions on the prevention and control of marine debris pollution have been promulgated internationally, such as the "London Convention" and the "MARPOL Convention"[3]. At the same time, China has also promulgated various laws and regulations, such as the "Regulations on the Management of Marine Dumping of the People's Republic of China" and the "Solid Waste Pollution Prevention and Control Law"[4]. Under the constraints of various policies and regulations, marine debris pollution has generally been alleviated to a certain extent. In 2017, about 33,000 tons of floating objects were collected on the coast of Japan, and a total of about 337,000 tons were collected from 2009 to 2017[5].

With the development of the maritime transportation industry, carbon emissions have increased accordingly. Carbon emissions will accelerate the rise in global temperature, and the melting of snow...
and ice will cause sea levels to rise. Carbon emissions can also lead to ocean acidification. More than 250 million years ago, the earth experienced a dramatic extinction crisis. About 90% of marine life was extinct due to ocean acidification[6]. It will take millions of years for the marine ecosystem to fully recover. Mainly considering the issue of carbon emissions, this paper uses the solar hybrid vessel designed by Yuan[7] to collect debris on the sea. The vessel adopts a fully enclosed design. Solar panels are laid on the top, bow and stern surface of the hull. The light energy absorbed by the panels is converted into direct current, which stores the electrical energy in the accumulator in the engine room of the hull to drive the vessel.

There is little research on the navigation routing of marine vessels in China. Shen[8] applied genetic algorithm to the research of inland vessel route optimization, and established the inland vessel route optimization model without time window constraint with the lowest transportation cost as the goal. Chen[9] discussed the coastal Inventory Routing Problem Based on power coal transportation, and proposed Lagrange relaxation approximation algorithm to solve the inventory and marine vessel routing problem. Wang[10] used the improved ant colony algorithm to solve the problem of vessel routing optimization. At present, most of the debris collection work is aimed at the debris on the beach, and there is little research on the debris in the ocean. Gang[11] and others first proposed a three-stage method for marine debris collection. Due to the characteristics of marine debris drifting over time, firstly, use satellites or drones to obtain the initial location of the debris through remote sensing; secondly, use the GNOME software with diagnostic mode to predict and locate the trajectory of the debris; finally establish a vessel routing optimization model and solve it. On this basis, this paper uses the logistics network method to optimize the route of marine debris collection vessels, with the goal of reducing collection costs.

2. Problem description

Marine debris collection vessel routing planning is a reasonable route for the vessel to better recover the debris in the ocean, which makes the collection time shortest or the collection cost lowest. The difference between marine debris collection and land debris collection is that the location of debris points on the sea is constantly changing under the action of wind and ocean current. Based on this characteristic, we use GNOME software to predict the trajectory of debris points and constrain the collection range of debris points in the form of time window. Through the prediction of the debris point data, we can plan the best route for the collection vessel.

What is different from the past is that we are using solar and diesel hybrid new energy vessels. Compared with traditional vessels, new energy vessels use clean energy, which will reduce the diesel energy consumption in the process of debris collection. As solar energy is a clean energy, carbon emissions are only emitted by diesel, so carbon emissions will be reduced a lot in the whole operation process, which can better protect the environment. For the convenience of modeling, we regard a port as two nodes, which are the starting point and the ending point respectively. The vessel dispatched from the starting point, served all the debris points and returned to the terminal again. It is assumed that the amount and weight of debris will not change with time when it floats in the ocean. In addition, debris will not sink into the water.

The model also considers the following assumptions: (1) a homogeneous fleet with limited weight and volume; (2) the speed of the vessel is fixed; (3) the weight and volume of debris at each debris point do not exceed the carrying capacity and volume of the vessel; (4) the position of debris is within the collectable range within a given time window.

3. The proposed methodologies

3.1. Description of parameters and variables

The problem is defined on a complete graph, where \( N \) is a set of points and \( A \) is a set of edge arc lengths. Node set can be divided into \( N = N_1 \cup N_2 \), where \( N_1 = \{1, 2, \ldots, n\} \) is the set of predicted marine debris, and \( 0 \) and \( n+1 \) represent the starting point and the ending point respectively. The arc set
is $A = A_0 \cup A_1 \cup A_2$, where $A_0 = \{(n_i, n_j)|n_i \in N_0, n_j \in N_1\}$ denotes the set of arc lengths from the starting point to the service point, $A_1 = \{(n_i, n_j)|n_i \in N_1, n_j \in N_1\}$ represents the arc length set from service point to service point, $A_2 = \{(n_i, n_j)|n_i \in N_1, n_j \in N_2\}$ represents the set of arc lengths from the service point to the end point. $P$ is a collection of vessels used to collect debris. $S$ is the set of speeds at which a vessel sails. Every node $i \in N$ has a service time $r_i$. Volume of debris $a_i$ Debris density $\rho_i$ and time window $[t^e_i, t^f_i]$, where $t^e_i$ and $t^f_i$ is the earliest time and the latest time. At the starting point of $N_0$, the accumulated weight $Q^o_{p0}$ and the accumulated volume $Q^o_{p0}$ are all 0, in addition, there is a berth fee for vessels at the terminal $t^b_i$ and debris handling cost $f^d_i$. $C^w_p$ and $C^o_p$ is the load and volume of the vessel respectively. In addition, the hourly rental and insurance cost of the vessel are expressed as $f^z_p$ and $f^a_p$. The fuel consumption per hour of the vessel is $f^v_p$, and the unit fuel cost of the vessel is $f^a_p$. The $\theta$ is $ca_2$ emission factor, $C$ is the total carbon emission. $v_s$ is the speed of different levels, where $s \in S$. The cumulative volume of vessel $p$ before point $i$ is $Q^v_{pi}$, the cumulative weight is $Q^w_{pi}$. The arrival time of the vessel at point $i$ is expressed as $t^a_{pi}$. Define $x_{ijps}$ is the decision variable, if the collection vessel $p \in P$ serves $(i, j) \in A$ at speed $s \in S$, $x_{ijps} = 1$, otherwise $x_{ijps} = 0$.

### 3.2. Mathematical model of vessel routing

The mixed linear programming model is as follows:

$$\begin{align*}
\min & \sum_{(i,j) \in A} \sum_{p \in P} \sum_{s \in S} f^v_p t_{ij} x_{ijps} + \sum_{i \in N_1} \sum_{j \in N_2} \sum_{p \in P} \sum_{s \in S} f^d_p x_{ijps} \\
& \quad + \sum_{i \in N_0} \sum_{j \in N_2} \sum_{p \in P} \sum_{s \in S} (f^z_p + f^a_p + f_r) (t^a_{pj} - t^a_{pi}) \\
& \quad + \sum_{j \in N_1} \sum_{p \in P} x_{0jps} = 1 & p \in P \\
& \quad \sum_{j \in N_1} \sum_{p \in P} x_{ijps} = \sum_{j \in N_1} \sum_{p \in P} x_{jps} & j \in N_1, p \in P \\
& \quad \sum_{j \in N_1} \sum_{p \in P} x_{ijps} = \sum_{j \in N_1} \sum_{p \in P} x_{i,n+1,ps} & p \in P \\
& \quad \sum_{i \in N_0 \cup N_2} \sum_{p \in P} x_{ijps} \leq 1 & j \in N_1 \\
& \quad t^a_{pi} + r_i + \frac{d_{ij}}{v_s} \leq t^a_{pj} + (1 - x_{ijps}) M_{ij} & (i, j) \in A, p \in P, s \in S \\
& \quad t^e_i \leq t^a_{pj} \leq t^f_i & j \in N, p \in P \\
& \quad Q^o_{pi} + a_i \leq Q^o_{pj} + (1 - x_{ijps}) C^o_p & (i, j) \in A, p \in P, s \in S \\
& \quad Q^o_{pi} \leq C^o_p & i \in N, p \in P \\
& \quad Q^w_{pi} + a_i \rho_i \leq Q^w_{pj} + (1 - x_{ijps}) C^w_p & (i, j) \in A, p \in P, s \in S \\
& \quad Q^w_{pi} \leq C^w_p & i \in N, p \in P
\end{align*}$$

(1)
\[ Q_{p_0}^0 = 0 \quad \text{if} \quad p \in P \]  
\[ Q_{w}^{o} = 0 \quad \text{if} \quad p \in P \]  
\[ \sum_{(i,j) \in A} \sum_{p \in P} \theta f_r t_{ij} x_{ijps} \leq C \]  
\[ x_{ijps} \in \{0,1\} \quad (i,j) \in A, p \in P, s \in S \]  
\[ Q_{pi}^{o}, Q_{pi}^{w}, t_{pi}^{a} \geq 0 \quad i \in N, p \in P \]  

The objective function (1) is to minimize the total cost of this debris collection. It mainly includes three parts: the first part is the fuel cost during the voyage; the second part is the berth cost and unloading cost during the collection process; the third part is the rental, insurance and labor cost during the whole voyage. The constraint (2) ensures the vessel departs from the port. Constraint (3) requires the equilibrium flow at the middle point to be conserved. The constraint (4) makes the departure port and return port of the vessel consistent. Constraint (5) ensures that each middle vertex is served by only one vessel. Constraint (6) is a restriction on time. It calculates the arrival time of the vessel from the departure port to the first debris point, and the arrival time of the remaining nodes including all other debris point locations and destination, where \( M_{ij} = t_i^l + r_i + \frac{d_{ij}}{v_{\text{min}}} \). Constraint (7) is to implement time window for intermediate point and destination port. The constraint (8) is used to calculate the cumulative volume of debris collected at each location on each vessel routing. The restraint (9) ensures that the accumulated volume of refuse collected by each vessel does not exceed the volume of the vessel itself. The constraint (10) is used to calculate the cumulative weight of debris collected at each location on each vessel routing. The restraint (11) ensures that the accumulated capacity of debris collected by each vessel does not exceed the weight of the vessel itself. Constraints (12) - (13) are initialization of debris weight accumulation and volume accumulation at the initial point. Constraint (14) is a constraint on carbon emissions. Constraint (15) is a variable declaration. Constraint (16) is a nonnegative constraint of a variable.

4. Solution and example analysis

4.1. Solution

We use the vehicle routing problem spreadsheet solver created by Günes Erdogan[13] to solve the model, which uses a large-scale domain search algorithm. The large-scale neighborhood search algorithm is the first method proposed by Shaw[12] (1998) to solve the vehicle routing problem, and it has been successfully applied to a variant of the vehicle routing problem. Its basic idea is to iteratively search the solution space by removing the vertices of a large number of current solutions and reinserting them to different positions. Compared with the destructive reconstruction algorithm, it has a larger search space and is less likely to fall into the local optimum, which increases the possibility of obtaining the global optimum. The algorithm uses four local search operators, namely service point exchange, 1-OPT, 2-OPT and vehicle exchange. The exchange operator searches for all possible points in a given solution and checks whether exchanging them will produce a better objective function value.

4.2. Example analysis

4.2.1. Data description

We take the port above as our departure port to collect debris in the East China Sea. Firstly, we use satellite to get the initial position of debris through remote sensing, and then use Gnome software with
diagnostic mode to predict and locate the trajectory of debris. Through the predicted data, the best route is planned for the collection of vessels. We predict the location of the selected 30 initial debris points, and the drift distribution in the prediction time is shown in Figure 1. We select four of these days to analyze, and the size of the point represents the amount of debris. Through the Day 4 distribution of debris in Figure 1, we can find that the distance of debris from the port is getting farther and farther, the distribution of debris points is also spreading, and the debris points have obvious drift.

The debris collection uses solar hybrid vessels. This type of vessel has a compact hull and advanced collection technology. We assume that the debris collection speed is 6 tons/hour. In this study, only this type of debris collection vessel is considered in the whole process of collection operation. Its main advantage is that it uses solar panels to generate electricity during navigation, which can save fuel during navigation and greatly reduce carbon emissions. We choose a solar hybrid vessel with PV penetration rate of 25%. Assuming that the specific parameters of the vessel are: load capacity of 10 tons, fuel tank capacity of 180 liters, light drainage tonnage of 10 tons, and Photovoltaic (PV) penetration rate of 20%, the navigation fuel consumption is 15 L/h.

For other price related parameters in the model, we refer to the market price set in 2020. Fuel diesel is 5 yuan/L, rental cost is 130 yuan/h, insurance cost is 50 yuan/h, labor cost is 20 yuan/h, berth cost is 50 yuan/day/vessel, unloading cost is 100 yuan/day/vessel. In the constraint, the carbon emission is set at no more than 1 ton per trip. The carbon emission per liter of diesel fuel is 2.675kg. In addition, we refer to Wu[14], the solar panels of new energy vessels need to be repaired after one trip, which will generate a fixed maintenance cost. We set the maintenance cost as 100 yuan for each vessel during one trip.
4.3. Result analysis

4.3.1. Impact of Debris Location Distribution on Collection Cost

The biggest difference between marine debris collection and land debris collection is that debris will be affected by ocean current and wind, and its location will change at any time. The real-time distribution of debris location will have a certain impact on the whole collection process. Figure 1 shows the distribution of the debris points we selected for four days. Through Figure 1, we find that the location of the debris is farther and farther away from the port, and the debris points are more and more scattered. The distance from the debris point to the port and the dispersion of the debris point will change the collection routing and collection cost. So it is very important to choose the right time to collect. In order to find the best collection time, we use the large-scale neighborhood search algorithm to solve the predicted seven day debris location distribution, and the results are shown in Figure 1.

![Figure 2. Total cost and total hour](image)

It can be found from Figure 2 that the change trend of the line chart of the collection cost and the line chart of the collection time required for debris collection is the same, which indicates that the collection cost increases with the increase of the debris collection time. The reason is that the total collection cost is closely related to the variable costs such as vessel rent, insurance, labor cost and fuel consumption cost. The longer the collection time is, the more variable costs will be generated. Among them, the total cost of the fourth day is the largest, which is 21318.38 yuan; the total cost and collection time of the second day are the least, which are 16930.61 yuan and 79.55 hours respectively; compared with the day with the largest collection cost, it saves 20.58% of the cost and 17.43% of the time. To sum up, it can be seen that it is the most advantageous to send vessels on the Day 2, with the lowest cost and the shortest collection time.

Therefore, we will choose the second day as the best time to send vessels for collection, which will result in the least cost. Table 1 shows the details of 30 debris points in the second day, in which the time window of collection is calculated by Gnome software, which is [8:00, 20:00]. We select the collection time, the weather is clear, and the small drift of the debris point is within our collection range. Table 2 shows the best vessel routing we found, where 0 is the port. Due to the limitation of vessel capacity and working hours, 8 vessels need to be sent for this collection.
Table 1. Location and weight of debris in Day 2

| Debris No. | Latitude (N) | Longitude (E) | Weight (tons) |
|------------|--------------|---------------|---------------|
| 1          | 31.576       | 122.492       | 1.0           |
| 2          | 30.671       | 121.805       | 1.6           |
| 3          | 32.285       | 122.067       | 1.8           |
| 4          | 32.206       | 122.791       | 1.5           |
| 5          | 32.084       | 122.408       | 1.4           |
| 6          | 31.181       | 122.839       | 1.5           |
| 7          | 30.577       | 122.799       | 2             |
| 8          | 31.353       | 122.990       | 2.5           |
| 9          | 30.834       | 123.099       | 1.8           |
| 10         | 30.524       | 121.510       | 2.6           |
| 11         | 32.142       | 121.836       | 2.1           |
| 12         | 31.206       | 122.392       | 3.0           |
| 13         | 30.466       | 122.182       | 3.5           |
| 14         | 30.895       | 121.942       | 1.8           |
| 15         | 30.912       | 122.036       | 2.5           |

| Debris No. | Latitude (N) | Longitude (E) | Weight (tons) |
|------------|--------------|---------------|---------------|
| 16         | 30.827       | 122.004       | 2.0           |
| 17         | 31.954       | 122.519       | 2.6           |
| 18         | 31.796       | 122.370       | 2.4           |
| 19         | 31.909       | 122.230       | 4.0           |
| 20         | 31.478       | 123.082       | 4.2           |
| 21         | 31.901       | 123.254       | 3.5           |
| 22         | 31.742       | 122.452       | 0.9           |
| 23         | 31.587       | 123.515       | 2.4           |
| 24         | 31.804       | 121.510       | 1.8           |
| 25         | 31.159       | 122.196       | 5.0           |
| 26         | 31.206       | 123.053       | 2.5           |
| 27         | 31.922       | 122.811       | 1.5           |
| 28         | 30.717       | 122.410       | 1.0           |
| 29         | 30.511       | 122.306       | 2.0           |

Table 2. Vessel Routing for Day 2

| Vessel No. | Routing       | Vessel No. | Routing       |
|------------|---------------|------------|---------------|
| 1          | 0-14-15-26-0  | 5          | 0-16-13-24-2-0|
| 2          | 0-10-0        | 6          | 0-11-3-5-4-17-0|
| 3          | 0-30-1-21-23-0| 7          | 0-27-19-18-22-0|
| 4          | 0-25-6-9-28-7-29-0| 8          | 0-20-8-12-0   |

4.3.2. Total cost and carbon emission under different PV penetration rates

The fuel consumption of vessels under different Photovoltaic penetration rates is shown in Table 3 below. Photovoltaic penetration refers to the percentage of electricity provided by distributed photovoltaic power generation in the total power consumption of the system[15]. When the PV penetration rate is 0%, it means that the vessel is a pure diesel vessel, and its unit fuel consumption is set according to the vessel used in Gang[11] and others' paper, and the unit hourly fuel consumption is 20 L/h. When the PV penetration rate is different, the fuel quantity per hour is set in proportion, as shown in Table 3 below. The unit fuel consumption of vessels is different under different PV penetration, so the collection cost and carbon emissions are different under different PV penetration. Since PV penetration is difficult to reach 100%, we do not consider the case of pure solar energy. We analyzed the collection cost and carbon emissions of different PV penetration rates based on the data of the second day's debris points. The PV penetration rate of vessels was 25% the next day.

Table 3. Fuel consumption under different PV penetration rates

| PV penetration | Fuel consumption (L/h) |
|----------------|------------------------|
| 0%             | 20                     |
| 25%            | 15                     |
| 50%            | 10                     |
| 75%            | 5                      |
Figure 3 shows the relation vessel between the total cost of debris collection from vessels and carbon emissions under different PV penetration rates. It can be seen from Figure 3 that with the increase of PV penetration, the total cost and carbon emissions show a downward trend. This is because the higher the PV penetration rate is, the smaller the fuel consumption per hour of the vessel will be, and the fuel cost will be reduced during the whole voyage, which will reduce the total cost of collection. Solar energy is a clean energy, and it will not produce carbon during navigation; however, it will change the photovoltaic permeability due to the influence of weather conditions and the intensity of sunlight. When the PV permeability decreases, the fuel consumption per hour will increase, and the increase of fuel consumption will lead to the increase of carbon emissions.

Under the influence of sunlight, when the average PV penetration rate is 75%, the collection cost is the lowest, which is 14219.12 yuan; when the PV penetration rate is 0%, the collection cost is the highest, which is 18264.36 yuan; compared with the two, the cost can be saved by 22.14%. When the average PV penetration rate is 75%, the CO2 emission is the least, which is 726.031kg; when the PV penetration rate is 0%, the CO2 emission is the most, which is 2873.838kg; compared with the two, the CO2 emission can be reduced by 74.7%. From the analysis of the overall change trend of the total collection cost and carbon emissions, the use of solar hybrid vessel is the best choice, which can not only save the cost of debris collection, but also reduce carbon emissions.

### 4.3.3. Capacity selection on total cost and carbon emission

Different types of vessels have different collection speeds for floating debris. This section will discuss the impact of the second day distribution of new energy vessels with different capacity under the same luminous penetration rate on the collection cost. Four vessel types are selected in this paper, and the specific parameters are shown in Table 4. A2 is the basic vessel type used above.

| Vessel type | Vessel capacity (t) | Fuel consumption (L/h) | Vessel Charter (¥/h) |
|-------------|---------------------|------------------------|---------------------|
| A1          | 7                   | 12                     | 100                 |
| A2          | 10                  | 15                     | 130                 |
| A3          | 15                  | 18                     | 160                 |
| A4          | 20                  | 19                     | 170                 |
Figure 4 shows the distribution of marine debris in the second day, the collection cost and total collection time of different types of vessels, and Figure 5 shows the relation vessel between the total collection cost and carbon emissions.

From the data in Figure 4, it can be found that compared with A2, with the decrease or increase of the vessel's rated carrying capacity, the cost of debris collection increases. The lowest collection cost of A2 was 16930.61 yuan. Compared with A2, A4 had the highest collection cost of 19206.67 yuan, with a cost growth rate of 11.85%. The choice of vessel type will directly affect the total collection cost. In the specified working time, choosing the vessel that matches the total weight of debris in the debris point will maximize the utilization of vessel capacity and minimize the total cost of collection. To sum up, it can be found that A2, that is, the vessel with a capacity of 10t, is the most favorable for debris collection, which can maximize the utilization of vessel resources and reduce the total cost.

Figure 5 shows the amount of carbon emitted by different types of vessels on the way of debris
collection on the second day. It can be found that A3 has the least carbon emission and A4 has the most carbon emission. The larger the vessel's capacity is, the more fuel is consumed and the more carbon is produced. Although the unit fuel consumption of A1 vessel is relatively small, due to the limitation of vessel capacity, the number of vessels used in the collection process is relatively large, which makes the total collection time longer, the total fuel consumption increases and the carbon emission increases. Through the analysis, it is found that the use of A3 can reduce carbon emissions by 12.44% compared with the use of large vessels.

Compared with A2, the collection cost of A3 increased by 663.92 yuan, the growth rate was 3.7%, and the carbon emission decreased by 25.812kg, the reduction rate was 1.18%. Compared with the two, the reduction rate of carbon emission is less than the growth rate of cost, so A2 is the best choice.

5. Conclusion
In order to protect the marine ecological environment, we collect and treat the marine debris, making the marine debris resources collection and social sustainable development. In this paper, we apply the logistics network to the routing optimization of marine debris collection vessel. The results show that:

1) It is very important to choose the right time to collect debris. After we get the debris location data, we can get the debris location data of the next few days through the prediction of the debris drift trajectory. After calculation, we can find the best time, which can save 20.58% of the cost.

2) By analyzing the collection cost and carbon emissions of vessels under different PV penetration rates, when the PV penetration rate is 75%, the cost can be saved by 22.14% and the carbon emission can be reduced by 74.7%

3) Choosing the right vessel type can effectively reduce the collection cost. In the example, through the analysis of four vessel types with different capacities, we find that the vessel type with 10 tons capacity is the most suitable one in the example. Compared with the vessel with 20 tons capacity, the total collection cost is reduced by 11.85%.

There are still some deficiencies in this study. Due to many factors in the marine environment, it is difficult to accurately locate the location and weight of debris, which affect our collection of debris. In particular, there is no reliable quantitative method to measure the weight of debris. Therefore, in the next step, we will use stochastic programming to optimize the problem.

References
[1] Zhao X., Qi, S.B., Liao, Y., et al. (2016) Investigation and Control of Beach Litter Pollution in China. Environmental science research, 29(10): 1560-1566.
[2] Wang, X.F. (2017) Research on marine litter pollution Problems under The Perspective of International Law. Zhejiang University.
[3] Peng, H.D. (2019) Research on International Law regarding Marine plastic Debris Governance. Shandong University.
[4] Zhang, J.X., Liu, Q., Zhang, C., et al. (2019) Study on the legislation of the marine plastic and micro plastic management. Marine environmental science, 38 (02): 167-177.
[5] Zhang, Y.X. (2019) Analysis of The Relevant Laws and Status quo of Marine Debris in Japan. Legal system and society, (06): 20-21.
[6] Li, Z.D. (2011) Hazards of ocean acidification. Encyclopedia, (20): 34-35.
[7] Yuan, Y.P., Wang, J.X., Yan, X.P., et al. (2018) A design and experimental investing Hang Station of a large-scale solar energy/diesel generator powered hybrid vessel. Energy, 165.
[8] Shen, H. (2010) Inland Vessel Route Optimization Based on Genetic Algorithm. Logistics technology, 29 (z1): 133-135.
[9] Chen, K. (2018) Short-term Coastal Inventory Routing Problem Based on Coal Transportation. Dalian Maritime University.
[10] Wang, H. (2016) Application of ant colony algorithm in the simulation of vessel routing optimization. Vessel science and technology, 38 (20): 7-9.
[11] Gang, D., Farjana, N., Morteza, A., et al. (2020) Vessel routing and optimization for marine
debris collection with consideration of carbon cap. Journal of Cleaner Production, 263.

[12] Shaw, P. (1997) A new local search algorithm providing high quality solutions to vehicle routing problems. APES Group, Dept of Computer Science, University of Strathclyde, Glasgow, Scotland, UK.

[13] Günes, E. (2017) An open source Spreadsheet Solver for Vehicle Routing Problems. Computers and Operations Research. 84:62–72.

[14] Wu, X.X. (2010) Application Analysis of Solar and wind Energy Application on The Vessel. Wuhan University of technology.

[15] Zhao, B., Hong, B.W., Ge, X.H. (2010) Study on Energy Permeability after Many Distributed Photovoltaic Power Supplies Connected to Grid. East China electric power, 38 (09): 1388-1392.