Research on reducing carbon emissions from logistics

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Abstract. The Earth is warming at an unprecedented rate. The carbon emissions generated by logistics and transportation have caused a lot of impact on the environment. It is extremely urgent to take certain actions to alleviate the energy consumption and carbon dioxide emissions of logistics and transportation. It is recommended to use other heuristic algorithms to optimize the path and distribution order to reduce the carbon emissions of the logistics and transportation industry while ensuring that the goods are delivered as required.

1. Introduction
The Earth is warming at an unprecedented rate. Since 1970, global temperatures have risen by 0.15°C every 10 years, and have risen by 0.7°C in the past 20 years [1]. Scholars, from various countries, have recognized that global warming will cause lots of problems such as deterioration of crop growth environment, extinction of some species, and rising sea level [2]. More scholars believe that the increase of sea surface temperature caused by global warming has an important impact on rainfall and rainfall frequency. There is a certain relationship between various extreme climates and climate warming. In recent years, there have been frequent climate anomalies such as droughts, floods, hurricanes, heat waves, etc., and the losses caused by them have been constantly refreshing their historical records. Words such as “One Hundred Years” have frequently appeared in people’s field of vision, and climate change issues are increasingly receiving the world. The issue of climate change is gradually attracting the attention of countries around the world.

The climate change conference for the purpose of signing a new agreement for global action on future climate change was held in Copenhagen with the intention of stopping the increase of greenhouse gas emissions through a “responsible sharing” approach. In order to cope with the severe challenges brought about by climate change and build a “resource-saving and environment-friendly” dual-type society, China has proposed independent emission reduction actions during the Hagen meeting. The "Twelfth Five-Year Plan for Development" proposes that the transportation industry fully meets the fuel consumption limit for operating passenger and cargo vehicles. Compared with 2005, the energy consumption of transportation capacity of operating passenger cars and trucks decreased by 6% and 12% respectively, and the carbon dioxide emissions of transportation units of operating vehicles decreased by 11%. [3]

The carbon emissions generated by logistics and transportation have caused a lot of impact on the environment.[4] It is extremely urgent to take certain actions to alleviate the energy consumption and carbon dioxide emissions of logistics and transportation. Logistics transportation often has serious problems of separation of forward and reverse logistics, which makes the vehicle no-load phenomenon more and more serious, thus increasing traffic volume, increasing road congestion, and ultimately
leading to increased distribution costs, which is contrary to the concept of low-carbon economy development. [5]

This paper applies the imperialist competition algorithm (ICA) for optimizing the logistics transportation route, distribution sequence, and minimizing the carbon emission of the vehicle under the premise of ensuring that the goods arrive at the customer's hands as required.

2. Description of the problem

The problem of distribution of logistics and transportation (PDLT) is generally described as: a) a single warehouse is identified as a distribution center, b) using a certain number of homogeneous vehicles to deliver goods to n customers as required; d) The vehicle has two limitations of capacity and load, e) Searching for the shortest path to minimize carbon emissions.

A set of n nodes \( V = \{0,1,2,\ldots,n\} \) represent receiving customers. The node 0 denotes the distribution center, while nodes 1 to n are vehicle destination. Further, we adopt the following notation:

- \( n \) the number of vehicle destinations
- \( m \) the number of destinations
- \( i,k \) index for number of destinations; \( i,k \in \{1,2,\ldots,n\} \)
- \( j \) index for vehicle; \( j \in \{1,2,\ldots,m\} \),
- \( L_i \) the load customer \( i \) requires
- \( B_j \) burden of vehicle,
- \( D_{i,k} \) the distance from \( i \) to \( k \)
- \( T_k \) the maximum load for vehicle \( k \)

\[
\begin{align*}
X_{i,k,j} &= 1, \text{ if vehicle } j \text{ visits destination } k \text{ immediately after destination } i; \\
0, & \text{ otherwise} \\
y_{i,j} &= 1, \text{ only if vehicle } j \text{ visits destination } i; \\
0, & \text{ otherwise}
\end{align*}
\]

The minimum carbon emissions of logistics problem model:

\[
F = \text{Min} \sum_{i=0}^{n} \sum_{k=0}^{n} \sum_{j=1}^{m} d_{i,k} X_{i,k,j} \left[ c_j \left( B_j - L_i \right) + c_0 \right] \\
\sum_{j=1}^{m} y_{i,j} = m \\
\sum_{j=1}^{m} y_{i,j} = 1, i=(1,2,\ldots,n) \quad (4)
\]

\[
\sum_{i=0}^{n} X_{i,k,j} = y_{k,j}, (j=0,1,2,\ldots,n; i\neq k; j=1,2,\ldots,m) \quad (6)
\]

\[
\sum_{k=0}^{n} X_{i,k,j} = y_{i,j}, (i=0,1,2,\ldots,n; i\neq k; j=1,2,\ldots,m) \quad (7)
\]

\[
\sum_{i=0}^{n} L_i y_{i,j} \leq B_j \quad (8)
\]

\[
\sum_{i=0}^{n} \sum_{k=0}^{n} X_{i,k,j} \leq |S| \quad (S \subset V; |S| \geq 2; k = 1,2,\ldots,m; i \neq j) \quad (9)
\]

Eq. (1) is the objective function to be minimized including the travelled load and distance. Among them, \( F \) is the carbon emissions of vehicles, \( f \) load the weight of the vehicle, \( c_0 \) is the carbon emissions per unit distance of the vehicle when empty, \( c_j \) is the carbon emissions per unit load unit distance when the vehicle is under load. Constraints (4) make sure that every vehicle starts from the warehouse. Constraints (5) ensure that apart from warehouse, each node is visited by a single vehicle. Moreover,
constraints (6) and (7) represent that each destination is linked only with another destination, one preceding it and the other following it. Constraint (8) ensures that each vehicle must be less load weight. Constraint (8) guarantee each vehicle’s single transportation route.

3. Imperialist competition algorithm
The ICA effectively guides the direction to search by generating empire, colonization assimilation, imperial competition, empire collapse, and iteratively loops through the imperialist countries that seek the greatest power. In order to more effectively avoid the traditional imperial competition algorithm falling into local optimum, the imperialist competition algorithm is used as the framework. After the colonization assimilation, the state power is increased through the national cultural revolution. The basic process of the imperialist competition algorithm with cultural learning ability is as follows:

![Flowchart of ICA](image)

Figure 1. The flowchart of ICA

a) Initialize the empire. Initialize the PDLT to N countries that represent D-dimensional optimization problems.
b) Measure the power of the countries by calculating the total carbon emissions of the PDLT. The power of the country is negatively correlated with the carbon emissions of PDLT.

c) When the colonial power in the imperialist group is greater than the imperialist power, the position of imperialism and the colonial state is exchanged; if not greater, the colonial state is assimilated. The process of assimilation of the colonial powers of the imperialist group is: (i) Move the colonial state to the empire according to the traditional ICA. (ii) It is judged whether the position after the movement is within the definition domain of the PFSP. If it is within the definition domain, the position is the final solution of the imperialist assimilation; if it is not within the definition domain, the position is defined as the temporary position. (iii) Based on the temporary location, find a new qualified location through the search strategy. A concrete example of the process of assimilation of imperialism is shown. The initial position of the colonial state is [1, 2, 3]. The position of the imperialist country in the imperialist group of the colonial state is [3, 1, 2]. Setting the moving distance $x=2$, the moving angle $\theta=0$, the new position after the colonial country moves is $[1.82, 1.59, 2.59]$. The coordinates are sorted from small to large as $1.59(2)<1.82(1)<2.59(3)$, and the corresponding dimension is numbered $[2,1,3]$, so the new country position after assimilation is $[2,1,3]$.

d) Select some countries to carry out cultural learning, refine strong cultures to form a dominant cultural library, and let some weak countries learn strong culture to strengthen national power. In order to enhance the effective exchange of cultural information between imperialist groups, ICA traverses various countries, statistically analyzes the culture of a strong country, uses the position matrix to record the cultural frequency in a strong country, and extracts the commonality of a strong national culture. The position matrix records the cultural information recorded in the n-dimensional vector in a strong country. That continuously increases the probability of a strong culture through cumulative iterations to highlight the advantages of strong culture in competition. In iteration, the traditional ICA only competes for the weak colonies through the competition of the imperialist group. The new ICA improves the communication and learning ability of each country by the refinement of the strong culture. Vulnerable countries can re-establish national culture according to the dominant culture of each imperialist group by comprehensively studying strong cultures to strengthen national power. However, the weak comprehensive power of the weak countries does not mean that any aspect is weaker than the strong ones; based on this, the weak countries can selectively learn the strong culture based on the original culture of the country. Therefore, two strong cultural learning strategies are generated through social behaviors in disadvantaged countries, one is comprehensive learning and the other is selective learning. Two learning strategies increase the diversity of the country, extend the search range of the algorithm, and effectively avoid falling into local optimum.

e) Competition of imperialist groups. Comparing the forces of the imperialist group, the powerful group has a greater probability of occupying the weaker countries in the weak group and strengthening the power of the imperialist group.

f) Meet the iterative criteria and stop iteration. With the constant loss of the imperialist colonial countries and the demise of the imperialist group, until the last empire is remained, the iterating is stopped. In order to avoid excessive loop iterations before converging into an empire, a reasonable iteration standard is set to stop the iterating.

4. Example result analysis
To verify the effectiveness of ICA, setting the parameter $n=24$, $m=3$, $T=200$. The specific solution results are as follows.

| Vehicles | Optimal path | The carbon emissions (kg) |
|----------|--------------|---------------------------|
| Vehicle 1 | 0→13→11→20→10→16→23→8→3→9→0 | 40.06 |
| Vehicle 2 | 0→1→12→24→15→18→7→19→0 | 39.22 |
| Vehicle 3 | 0→21→4→6→5→22→17→14→0 | 38.65 |
Through the ICA meta-heuristic algorithm, the distribution route and distribution order of goods with the lowest carbon emissions can be obtained, which can reduce carbon emissions and protect the environment.

5. Conclusion
The carbon emissions generated by logistics and transportation have caused a lot of impact on the environment. It is extremely urgent to take certain actions to alleviate the energy consumption and carbon dioxide emissions of logistics and transportation. This paper applies ICA for optimizing the logistics transportation route and distribution sequence, minimizing the carbon emission of the vehicle. It is recommended to use other heuristic algorithms to optimize the path and distribution order of PDLT, to reduce the carbon emissions of the logistics and transportation industry while ensuring that the goods are delivered as required.

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