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Low-Carbon Economy in Urban Solid Waste Logistics Management

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Abstract: With the development of scientific research and engineering practice, the amount of refractory waste is increasing gradually, and algorithms for the logistics management of waste have gained attention. Because there are a lot of obstacles in the city, solid waste will increase the field distance during transportation, thus producing a lot of Oxocarbon, which will promote the greenhouse effect. In order to reduce carbon production in the process of urban solid waste logistics management, this research improves the brainstorming algorithm based on low-carbon economy and discussion. The study first proposes a large number of different ideas based on the low-carbon economy. Then, through fitness comparison, the idea of clustering centers is further optimized. For similar ideas that arise during the thinking process, research has added mutation factors to facilitate ideas jumping out of local optima. Finally, the proposed fusion algorithm will be tested on the Logis dataset to calculate the carbon emissions of solid waste transportation devices within a day and compared with three models, such as brainstorming based on discussion. The motion distances of the four model design paths are 22 km, 23 km, 26 km, and 27 km, respectively, with corresponding carbon emissions of 3.9 t, 6.0 t, 6.8 t, and 8.9 t, respectively. The experimental results showed that the proposed model not only had the shortest design path but also had the lowest carbon emissions, which was in line with the current low-carbon economy environment. The application of this model in the rational transportation of urban solid waste will be useful. It is a novelty to integrate the idea of a low-carbon economy into the DMBSO algorithm, which can effectively deal with the carbon growth of the environment.

Keywords: Low carbon economy, brainstorming optimization algorithm, the best idea, variation factor, solid waste transportation

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1. Introduction

Against the backdrop of the rapid development of the engineering and construction industry, the total amount of urban solid waste has sharply increased, and the logistics management methods of waste have gradually entered the perspective of experts and scholars (Gao et al., 2022; Guo et al., 2022). As cities are densely populated areas, obstacles such as transportation facilities and equipment can interfere with the transportation of solid waste, adding more carbon emissions to the management process. In each partition of the city, the number of solid waste storage devices varies, and the location of solid waste destruction devices varies (Sharmila et al., 2022). With the extension of transportation time, the complex biochemical reaction between garbage will also increase the total amount of Oxocarbon. In order to conform to the current Low-carbon economy, the discussion mechanism-based Brain Storm Optimization (DMBSO) algorithm has received widespread attention. This algorithm has superior performance in the logistics management of urban solid waste due to its consideration of the fitness of each idea during runtime. However, it generates too many ideas, and similar types of ideas are prone to falling into local optima (Tang et al., 2020). In order to solve this problem, this study innovatively adds mutation factors to ideas, enabling them to have the ability to mutate and generate fusion algorithms (VLC-DMBSO). The main content of the study can be divided into four parts. Section 1 mainly analyzes and summarizes the current application of discussion-based brainstorming. Section 2 presents the use of mutation factors and introduces them into DMBSO. Section 3 contains the simulation experiments on the Logis dataset. The last section analyzes and compares the performance of this model with traditional models and points out the shortcomings that still exist in the research. The practical significance of this study lies in alleviating the tight trajectory of waste logistics and accelerating the transportation speed of urban solid waste. Intended to reduce carbon emissions from urban solid waste logistics and thereby alleviate the greenhouse effect. The novelty of the research lies in the combination of low-carbon economy thought in the DMBSO algorithm, which can effectively alleviate the carbon growth of the environment.

2. Related Works

In the logistics management of urban solid waste, research is widely distributed internationally. In order to find the minimum distance for transporting garbage and establish a model to reduce the required time, Puspita et al. (2020) established a peer-to-peer open time window based on demand robustness. The authors of the cited paper believed that these times were called deadlines, and as the distance traveled by vehicles increased, the more garbage the vehicles carried. The experimental results showed that the authors' model, compared with similar problems in previous studies, improved its robustness and can obtain the optimal path, reducing the time for garbage transporters to transport garbage. Zhang et al. (2022) optimized the transportation route of garbage trucks to minimize transportation costs and maximize residents' satisfaction and established an optimal robust model for urban domestic waste collection and transportation. The authors of the cited paper defined resident satisfaction as a penalty cost and adopted robust optimization methods to adapt to changes in garbage volume. The authors also conducted a case study on the transportation of municipal solid waste and verified the solution to determine the validity of their model. The experimental results indicated that the impact of changes in working hours and time windows on total costs was directly proportional, and the authors' methods can help residents make reasonable choices while considering the balance between total costs and service levels. With the gradual increase of garbage, research based on brainstorming algorithms has developed. Lenin (2021) solved reactive power optimization problems based on brainstorming optimization algorithms, while also considering quantum-based brainstorming optimization algorithms. The author of the cited paper proposed Hamiltonian cycles in optimization algorithms to avoid falling into local optima. In the proposed algorithm, quantum states were represented by wave functions, replacing modernization in brainstorming optimization algorithms. The proposed amplification brainstorm optimization was tested on a testing system, and the experimental results showed that the proposed algorithm can effectively reduce power loss. Lenin (2020) proposed a chaotic predator-prey method based on the brainstorm optimization algorithm to solve reactive power problems. The author used predator-prey brainstorming optimization to locate the cluster center as the predator and used other ideas as prey. In the proposed algorithm, the Chaos theory was used to model the algorithm, and the ergodicity of chaos was used to make the algorithm jump out of the local optimum. The author conducted tests on the testing system, and the experimental results showed that his algorithm can effectively reduce active power loss.

With the entry of industrial modernization, the algorithm based on a low-carbon economy has gained attention. In order to adjust the economic dispatch of wind power, Yan et al. (2023) reduced the cost of electricity by the source of the system through the transformation of the carbon and wind power market. The proposed model contained risk operating costs to illustrate the impact of changes in output on the system. The authors used carbon indicators to reduce system carbon emissions in the model and based on the impact of different carbon emission trading prices on the system. Finally, the authors used the ant-lion optimization method, combined with the golden sine theory, to conduct experiments to prove the rationality of the model the authors proposed. Zhang et al. (2020) proposed a power allocation method based on low-pass filters, and the authors' strategy coordinated the battery and capacitor to improve the battery environment. The authors controlled the state of charge of the battery and capacitor and corrected the output with the time of the filter. In order to eliminate the influence of environmental uncertainties, the authors used Monte Carlo simulation to avoid the problem of capacitor and battery allocation algorithms easily falling into local optima. Through the authors' method, although the number of capacitors remains unchanged, the number of batteries decreased by 10, indicating that their method was cost-effective.

Through the research of many experts and scholars, it is found that the algorithm research of urban solid waste logistics and the research based on the low-carbon economy is very popular, but there are few studies linking the two. This research creatively considers both discussion and low-carbon economy and is based on urban solid waste logistics management modeling. First of all, according to the low-carbon economy, a large number of different kinds of ideas are put forward. Then, through the comparison of fitness, the idea of a clustering center is further optimized. For the problem of similar ideas in the process of thinking, the variation factor is added to make the ideas jump out of the local optimum. The practical contribution of the research is to reduce the carbon emission of municipal solid waste logistics and then alleviate the greenhouse effect.

3. Urban Solid Waste Logistics Management Model

When humans use the mind to think, the ideas in this process can be used for biomimetics, and the Discussion Mechanism Based Brain Storm Optimization (DMBSO) algorithm is one of them. Similar methods include the ant colony algorithm and genetic algorithm. The advantage of the ant colony algorithm is that it can find better solutions to large-scale problems and is more robust. However, there are problems with the convergence speed of the ant colony algorithm. The advantage of the genetic algorithm is that it can carry out a wide range of global searches and can deal with complex optimization problems without being limited by the specific forms and constraints of the problems. However, it is easy for the genetic algorithm to fall into local optimal solutions. In order to design the Low-carbon economy route of urban solid waste logistics, this study builds a model based on Low-carbon economy and DMBSO. Firstly, the construction method of the model is described, and then its application is explored in solid waste transportation. Finally, the research proves the correctness of the research method and shows that it is an appropriate basis.

3.1. Brainstorm Algorithm

DMBSO will generate any number of ideas after thinking, and if one of the ideas is chosen as the clustering center of DMBSO, the remaining ideas will move in this direction (Ünver et al., 2022). They intersect at the cluster center and then discuss and retain excellent ideas. The comparison method is shown in Eq. (1).

$$\begin{cases} mp_j = \dfrac{|num_j|}{NI} \\ X_{ne} = X_S + \xi * N(\sigma,\mu) \end{cases} \quad (1)$$

In Eq. (1), the type of idea is denoted as j, the number of ideas in that class is denoted as num_j, the total number of ideas is represented by NI, and the weight ratio of each type of idea to all ideas is denoted as mp_j. The new idea after discussion is recorded as X_{ne}, the medium used X_S, $N(\sigma,\mu)$ representing the function of expectation σ and variance μ of the idea. The slope of the function is represented by the step size ξ of the entire idea set, and its calculation formula is shown in Eq. (2).

$$\xi = \log sig\left(\frac{\max_{it} - now_{it}}{2k}\right) * ran \quad (2)$$

In Eq. (2) above, the transfer method between ideas is denoted as sig, which is presented in logarithmic form. The preset and current iteration times are denoted as $\max_{it}, now_{it}$, and the degree of inclination of the sig curve is represented by k. The value of ran satisfies randomness, which is inversely proportional to the number of ideas and is within the range of $[0,1]$. The discussion mechanism occupies an important position in brainstorming, and the process it participates in is shown in Fig. 1 (Chang et al., 2021).

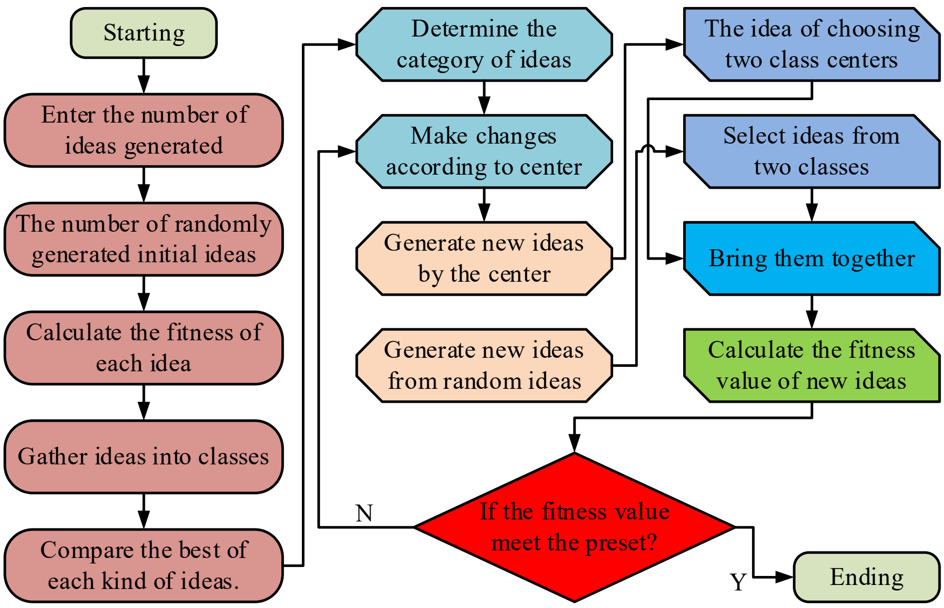

Fig. 1. Workflow diagram of brainstorming optimization algorithm based on discussion mechanism

Fig. 1 shows a brainstorming flowchart with discussion participation. Firstly, generate the idea of a random number in the model and record it as NI. Then calculate their fitness f_{NI} separately, and ideas with similar fitness can be grouped into the same category. Then, through discussion, determine the optimal idea for each clustering center and adaptively change the surrounding ideas based on this center. Finally, randomly select two cluster sets, extract their cluster centers and random ideas, calculate their fitness, and aggregate them together. Determine whether the fitness meets the preset requirements. If so, output the final result and end the workflow. Otherwise, make new changes to the idea based on each clustering center. In this process, the rules for generating new ideas from two ideas follow Eq. (3) (He et al., 2023).

$$Rule = f_{NI} Random_1 + (1 - f_{NI}) * Random_2 \quad (3)$$

In Eq. (3), $Random_1, Random_2$ represent the ideas extracted at the centers of two random clusters. After brainstorming, DMBSO's work will output many different kinds of ideas, including ideas related to the low-carbon economy. Carbon emissions are an important factor that must be considered when working in industries, and they are closely related to a warm environment (Cervantes-Castillo and Mezura-Montes, 2020). Therefore, in the operation of the company, reducing carbon emissions is the primary condition. The ideas based on the low-carbon economy include important ideas with innovative significance and conservative ideas with a guiding role. The relationship between them is shown in the following Eq. (4).

$$\Delta F_{mean} = (NI - 1)^{-1} \sum_{i=1}^{NI} \left[F(S_i) - F(S_{most}) \right] \quad (4)$$

In Eq. (4) above, the random guiding idea is represented with S_i and its fitness value denoted as $F(S_i)$; S_{most} represents random innovative ideas, its fitness value is $F(S_{most})$. These two types of ideas can be divided into the same cluster I, and the mean fitness of the cluster is denoted as ΔF_{mean}. In order to avoid a calculated ΔF_{mean} value of 0, this study defines the total number of clusters in the calculation process as subtracted by one. At this point, the Euclidean distance between the optimal ideas can be calculated, as shown in Eq. (5).

$$\Delta Ou_{mean} = (NI-1)^{-1}\sum_{i=1}^{NI}\sqrt{\sum_{j=1}^{D}\left(\alpha_{i,j}-\alpha_{best,j}\right)^2} \tag{5}$$

In Eq. (5), j represents the dimension in which the idea is located, and the output values of $F(S_i)$ and $F(S_{most})$ in that dimension are denoted as $\alpha_{i,j}, \alpha_{best,j}$. The global search ability of this dimension is denoted as D, and the Euclidean distance calculated based on each idea can be clustered into the set J (Yu and Zhao, 2021). Set I clusters ideas with strong fitness together, while set J contains all ideas around I. Through the operation of these two sets, the optimal idea under the Low-carbon economy can be run, and the operation formula is shown in Eq. (6).

$$\begin{cases} INno_{NI} = I \cap J \\ Con_{NI} = I - I \cap J \end{cases} \tag{6}$$

In Eq. (6), the pioneering ideas contained in all ideas are denoted as $INno_{NI}$, located at the intersection of I and J. The characteristic of the remaining ideas is to hold a reserved opinion, represented by Con_{NI}. Brainstorming considering Low-carbon economy in the discussion is a fusion algorithm (DMBSO Considering Low Carbon Economy, LC-DMBSO), in which ideas are widely distributed in the search area. Both types of ideas will move towards the feature set during the classification process. At the intersection of two sets, the ideas contained are characterized by the intersection of I and J. In Fig. 2 (b), there are still some unclassified ideas due to the limited size of the set. In order to expand the scope of both, this study innovatively introduces the idea-based approach, which aims to construct new ideas based on this idea and discuss the optimal DMBSO idea in a low-carbon economy. The calculation method for this idea is shown in Eq. (7).

$$\omega_{new}^{d} = \begin{cases} \omega_l^d + \left(\omega_u^d - \omega_l^d\right) * random & random \le \Pr \\ \omega_s^d + \left(\omega_a^d - \omega_b^d\right) * random & others \end{cases} \tag{7}$$

In Eq. (7), the calculated value of the idea in dimension d is denoted as ω_{new}^d, and the upper and lower limits of that dimension are represented by ω_u^d, ω_l^d, respectively. The probability of repetitive work is denoted as $\Pr$, which is a constant with a value of 0.005. $random$ is a random value on $[0,1]$, and by comparing it with $\Pr$, the calculation method of ω_{new}^d can be changed. ω_a^d, ω_b^d the calculated values of two random ideas in this operation, and the new ideas born K ω_{new}^d are denoted as ω_s^d. The actual carbon emissions using this idea can be calculated using a, b, u, l, s, new, as shown in Eq. (8).

$$\varepsilon = av + bv^2 + uv^3 + lv^{-1} + sv^{-2} + newv^{-3} \tag{8}$$

In Eq. (8), v represents the carbon emission rate of a certain type of work. Eq. (8) can be used to calculate the carbon emissions of urban solid waste logistics management, thereby achieving its low-carbon economy (Oslund et al., 2022).

3.2. Fusion Algorithm LC-DMBSO and Urban Solid Waste Logistics Management Model

In the management of urban solid waste logistics, the LC-DMBSO algorithm partitions the city during operation to achieve its efficiency. Each area of the city adopts a series working method, where all areas work simultaneously. In the LC-DMBSO algorithm for logistics management of urban solid waste, this study proposes an acceleration ratio to measure the work efficiency of LC-DMBSO, as shown in Eq. (9) (Yu et al., 2020). Appropriate methods can be adopted to optimize computational efficiency and ensure the safe operation of the LC-DMBSO algorithm.

$$MS_p = MT_1 / MT_p \tag{9}$$

In Eq. (9) above, the time required for the fusion algorithm to transport garbage once within any urban partition is MT_1, and the time consumed by a single garbage logistics within P urban partitions is recorded as MT_p. This study sets the number P of urban partitions to 12, so the analysis of solid waste displacement is a typical one-to-many problem for the LC-DMBSO algorithm (Lee et al., 2021). This problem is manifested in the form of linear programming in the function, as shown in Eq. (10).

$$Func = \sum_{t=1}^{T+1} h_0 * \ln(v\gamma_t) + \sum_{t=1}^{T+1}\sum_{i=1}^{N} h_i * \ln(v\beta_{t,i}) + \sum_{t=1}^{T+1}\sum_{i=1}^{N}\sum_{j=1}^{N}\chi_{t,i,j} \tag{10}$$

In Eq. (10), h represents the height of buildings in the urban partition, γ is the distance for garbage transportation, and transportation device parameters are represented by β and χ. One of the four solid waste storage stations is randomly selected in the urban partition, and the study sets them as four surrounding stations. The information exchange between them is shown in Fig. 2.

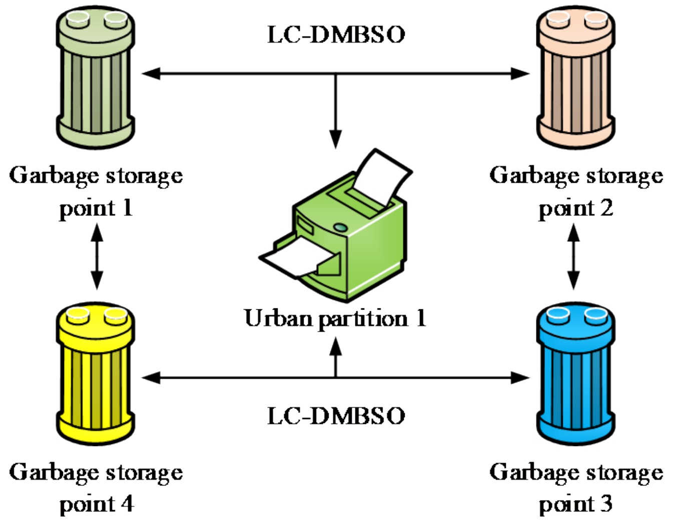

Fig. 2. Communication between random urban zoning and solid waste storage stations

In the solid waste logistics management shown in Fig. 2, the urban area is located as a liaison station, with four solid waste storage points evenly distributed around the area. When the LC-DMBSO algorithm works, information is disseminated between urban zoning and garbage stations through two-way communication. After information is transmitted from the partition to each garbage station, there is also information exchange between them, and message iteration is carried out in this way (Duarte et al.2020) . During the iteration process, obstacles along the garbage logistics route become parameters, which also affect the transportation device. The calculation of this impact is shown in Eq. (11).

$$\begin{cases} \ln\left(v\beta_{t,i}\right)+\eta_{t,i} \geq t_i & t\in[1,T], i\in[1,N] \\ \chi_{t,i,j} \geq 0 & t,i,j\in[1,T+1] \end{cases} \tag{11}$$

In Eq. . (11), $\eta_{t,i}$ is the time consumed to avoid obstacles during garbage management. In order to avoid such losses, this study plans the garbage logistics path to minimize collisions with unnecessary obstacles. By accelerating the convergence speed of the algorithm, it can not only shorten the total time of garbage logistics but also reduce carbon emissions during transportation. This study improves the fusion algorithm by adding mutation factors to the LC-DMBSO algorithm to generate an upgrade algorithm (VLC-DMBSO), which follows the rules shown in Eq. (12) during operation.

$$V_i = SP_1 + Zoom*\left(SP_2 - SP_3\right) \tag{12}$$

In Eq. (12) above, the number of variation factors added is denoted as V, and their scaling ratio is represented by $Zoom$. In the idea cluster, the three randomly selected ideas during VLC-DMBSO denoted as V, and their scaling ratio is represented by $Zoom$. By using this upgrade algorithm, obstacles along the way of garbage transportation can be avoided, and the optimal path for garbage logistics management in a low-carbon economy can be planned (Mumby et al., 2021). The algorithm also considers the loading capacity of the transportation device during operation and adopts the principle of proximity to handle it, as shown in Fig. 3.

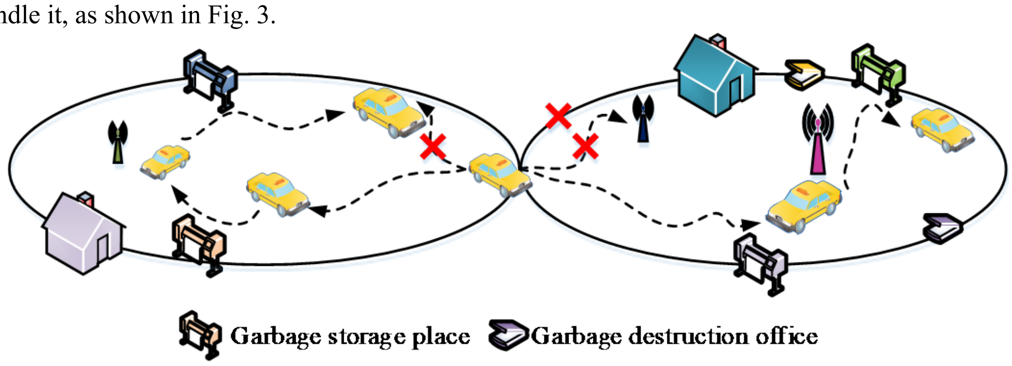

Fig. 3. Management path of waste logistics in a low-carbon economy with VLC-DMBSO planning

Fig. 3 shows the motion path between VLC-DMBSO-designed urban solid waste storage stations. There are multiple signal towers distributed in the city, which can control the signal of moving urban solid waste logistics management equipment to avoid obstacles such as trees. This path design scheme not only plans the optimal path but also closes the secondary path, making logistics management equipment more efficient and lower carbon economy (Wang et al., 2020). Due to the fact that the equipment only has three recycling stations for solid waste when fully loaded, the optimization algorithm continues to work, controlling the movement of the logistics management equipment toward the nearest urban solid waste disposal station at this time (López-Sánchez et al., 2020). In this process, the study considers the path intersection of multiple destruction areas and establishes a formula as shown in Eq. (13).

$$SP = \begin{cases} \varpi_{\theta,\vartheta} & \theta \le CR \text{ or } \vartheta = \vartheta an \\ \rho_{\theta,\vartheta} & others \end{cases} \tag{13}$$

In Eq. (13), the number of rows and columns of the mutation factor is denoted as θ, ϑ, the feature vector of the position mutation idea is represented by $\varpi_{\theta,\vartheta}$, and the feature vector of the target idea is denoted as $\rho_{\theta,\vartheta}$. The similarity in ideas between the two is noted as CR, the range of values ϑan is natural numbers. Mapping the intersection of ideas to the macro level is the overlap of multiple solid waste logistics management channels within the urban area. At the cluster center composed of these roads, the best ideas of the current category will be compared with $\rho_{\theta,\vartheta}$ to obtain lower carbon ideas. The comparison method is shown in Eq. (14).

$$\rho_{\theta,\vartheta} = \begin{cases} \varsigma_{ce} & func(\varsigma_{ce}) \prec func(SP) \\ \rho_{\theta,\vartheta} & others \end{cases} \tag{14}$$

In Eq. (14), the reference idea is denoted as ς_{ce}. The better ideas generated by comparing two ideas can form a new set (Alias et al., 2021). Due to the similarity of the ideas in this set, as the number of iterations increases, the VLC-DMBSO grouping of ideas may result in errors, such as labeling the correct ideas as noise. To avoid this issue, this study compared the linearity between ideas in the same set to select the path with the lowest carbon emissions and established the process shown in Fig. 4.

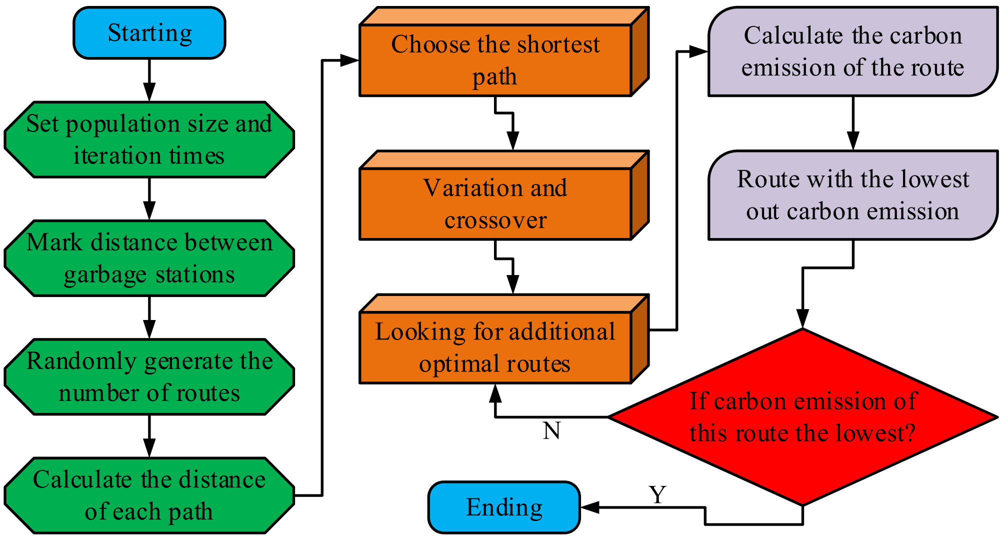

Fig. 4. Selection process of the lowest path of carbon emission

Fig. 4 shows the process of finding low-carbon pathways in urban areas. Firstly, set the search domain and maximum number of iterations for the VLC-DMBSO algorithm. Then, mark the distance between garbage storage locations and calculate the shortest path between them. Even the shortest path can have too many obstacles. Under the same operating time conditions, this path has higher relative carbon emissions. So, study and calculate the carbon emissions at this time and select the path with the lowest carbon based on the mutation method. When the carbon emissions meet the algorithm's preset, or the number of iterations reaches, the algorithm outputs the path and ends the operation. Otherwise, it searches for the shortest path again. If there is an overlap in the path length during the calculation process, Eq. (15) is used to round it down.

$$Road_{choose} = \left[\tau + \upsilon * (\psi - \tau)\right] \tag{15}$$

In Eq. (15), ψ, τ represent the longest and shortest paths in the urban partition, respectively. In the logistics management of urban solid waste, the low-carbon economy is an important goal, aiming at reducing carbon emissions and resource consumption. The VLC-DMBSO algorithm can be applied to optimize the decision-making problems in urban solid waste logistics management, such as the path planning of garbage collection vehicles and the layout of garbage bins. Optimizing the logistics management of municipal solid waste through the VLC-DMBSO algorithm can maximize the goal of the low-carbon economy. The algorithm can consider multiple factors, and through continuous iterative optimization, the optimal logistics management scheme can be obtained, which can improve the efficiency and sustainability of municipal solid waste logistics.

4. VLC-DMBSO Algorithm Application Verification

This study used the VLC-DMBSO algorithm to construct a path exploration model to verify the effectiveness of the algorithm in urban solid waste logistics management under a low-carbon economy. The superiority of using the Logis dataset was studied to validate the model and analyze the application scope of the model based on simulation experiments. There are 875 roads with different road conditions in this data set, which belong to all kinds of weather, and these roads are located in 20 cities.

4.1. VLC-DMBSO Model Performance Analysis

In order to verify the effectiveness of the VLC-DMBSO algorithm in urban solid waste logistics management under the low-carbon economy, this study conducted experimental verification on the Logis dataset obtained from the experiment. Due to the limited amount and types of data in this dataset, the dataset was divided into two parts: the training set and the test set, each accounting for 25% and 75%, respectively. The equipment parameters that need to be debugged in the experiment are shown in Table 1 (Yu et al., 2021). VLC-DMBSO algorithm uses variable length coding to represent the solution space of urban solid waste logistics management problem, and each solution is coded as a binary string, in which each bit represents the value of a decision variable. Through variable length coding, VLC-DMBSO can flexibly represent different lengths of paths and then calculate their corresponding objective function values. After each iteration, the VLC-DMBSO algorithm updates the position of the solution according to the fitness value of the current solution. Through multi-objective optimization, VLC-DMBSO can obtain a set of optimal solutions which have good performance in urban solid waste logistics management.

Table 1. Experimental parameters of model test

Device type	Operating parameters or software
Operating system	Windows XP
Central Processing Unit	16-core CPU
Main frequency	12.80 GHz
System memory	16.00 G
Execution method	Matlab R2022b
Language	Easy Chinese
Number of ideas	10^0-10^3
Urban zoning	Banlieue 13
Average number of obstacles	5
Data set	Logis
Probability of variation of ideas	0.5
Method of inspection	VLC-DMBSO

When the fusion algorithm proposed in the study is used for solid waste logistics management in real cities, it is not only necessary to consider the shortest planned path but also to minimize the carbon emissions of that section of the path. This study used VLC-DMBSO to conduct simulation experiments on the data in the Logis dataset. By testing the iteration error and F1 value, and comparing the experimental results with the Discussion Mechanism Based Brain Storm Optimization (DMBSO) algorithm, Random Forest (RF) algorithm, and Long and Short Term Memory Network (LSTM), the image is drawn as shown in Fig. 5. The advantage of the DMBSO algorithm is that it can search for the optimal solution by brainstorming and making full use of group wisdom and creative thinking. It can deal with the optimization problem of path design and has good global search ability. RF algorithm can deal with high-dimensional data on municipal solid waste operation and management and is highly accurate. The LSTM algorithm has advantages in processing time series data. It can not only evaluate the importance of features but also has advantages in processing missing values and unbalanced data. They have different advantages in the face of urban solid waste logistics management, so the study compares these three algorithms with the VLC-DMBSO algorithm proposed in the study.

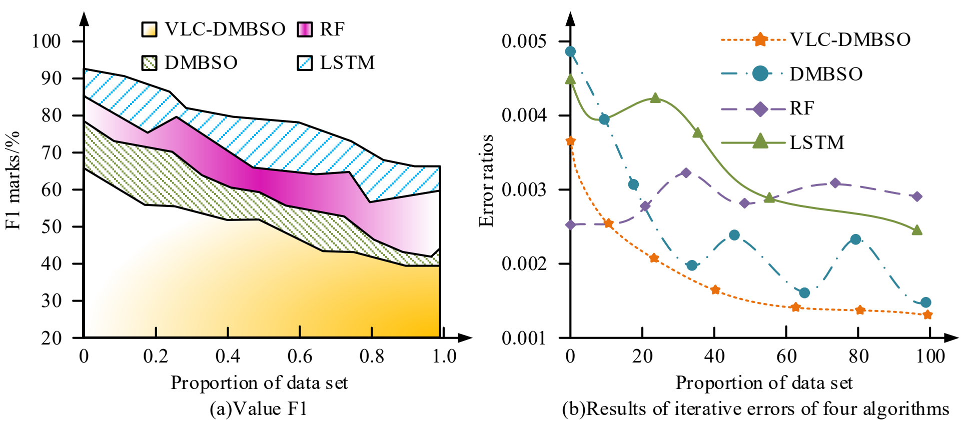

Fig. 5. Iterative error curves and F1 value determination of four models

From Fig. 5(a), it can be seen that as the number of iterations involved increases, the F1 values of all four algorithms show a downward trend. The algorithm proposed in the study showed the best performance among them, with an F1 value of 46% for this point when the dataset ratio was 0.64. The lowest F1 values for the other three models were 56%, 62%, and 74%, respectively. Fig. 5(b) shows the variation of the error values of the four models with the number of iterations. When the number of iterations was 62, the error performance of VLC-DMBSO was the lowest, at 0.0013. The minimum error values for DMBSO, RF, and LSTM were 0.0015, 0.0024, and 0.0023, respectively. The study believed that the superiority of the algorithm was not comprehensive enough based solely on the iteration error and F1 value, so their accuracy and loss rate were tested in this study, as shown in Fig. 6.

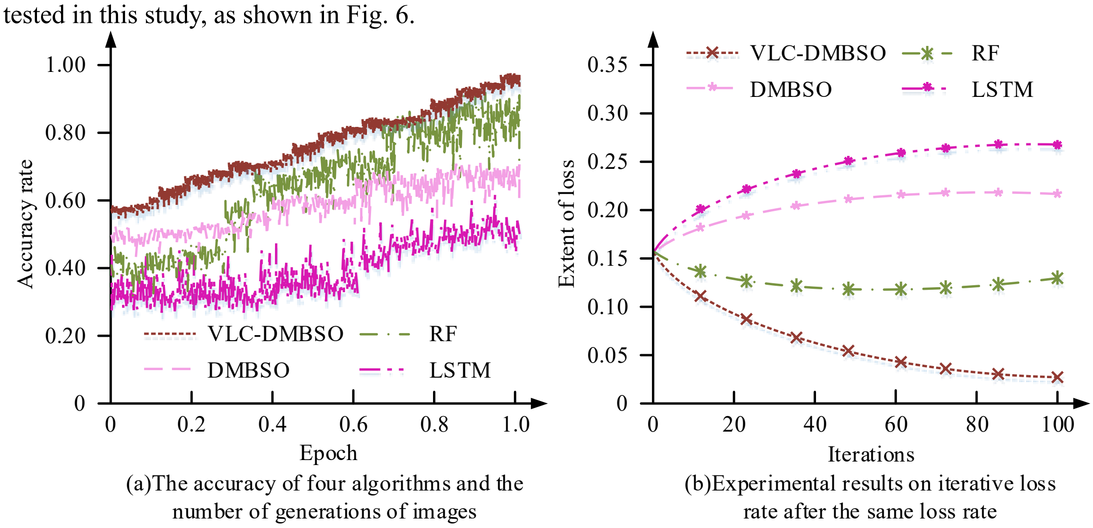

Fig. 6. Accuracy rate and loss rate of four models

Fig. 6 shows the comparison between the accuracy and loss rates of four algorithms. From Fig. 7(a), it can be seen that VLC-DMBSO has the highest accuracy among the four algorithms, at 0.94. When the number of iterations was 62, the loss rates of the four algorithms shown in Fig. 6(b) were 0.04, 0.12, 0.20, and 0.26, respectively. After 62 iterations, the loss rates of all four models showed a stable trend. So this study ultimately determined that the number of iterations was 62, and under this condition, the VLC-DMBSO algorithm had the best performance in all parameters, and the experimental performance of the model was the best.

4.2. VLC-DMBSO Model Verification

In order to verify the low-carbon effect of the VLC-DMBSO model in urban solid waste logistics, this study first set the experimental parameters and then conducted simulation experiments on the Logis dataset (Wang et al., 2022).

Table 2. Experimental parameters of municipal solid waste logistics based on low carbon

Device type	Operating parameters or software
Operating system	Windows 8
Number of variation factors	25
Initialization coefficient	0.005
Unimodal function	Spark DMBSO
Number of obstacles	$3*10^2$
Language	Easy Chinese
Number of urban districts	12
Area of urban area	35 square kilometers
Distance of the longest main road	22 kilometers
Data set	Logis
Number of ideas	100
Method of inspection	VLC-DMBSO

The study divided the city into 12 regions and used VLC-DMBSO, DMBSO, RF, and LSTM for path planning to select the minimum carbon path required to complete the task while avoiding various obstacles. The data obtained from the experiment was included in the Logis dataset, and the study was analyzed based on the Logis dataset. The experimental process diagram is drawn as shown in Fig. 7.

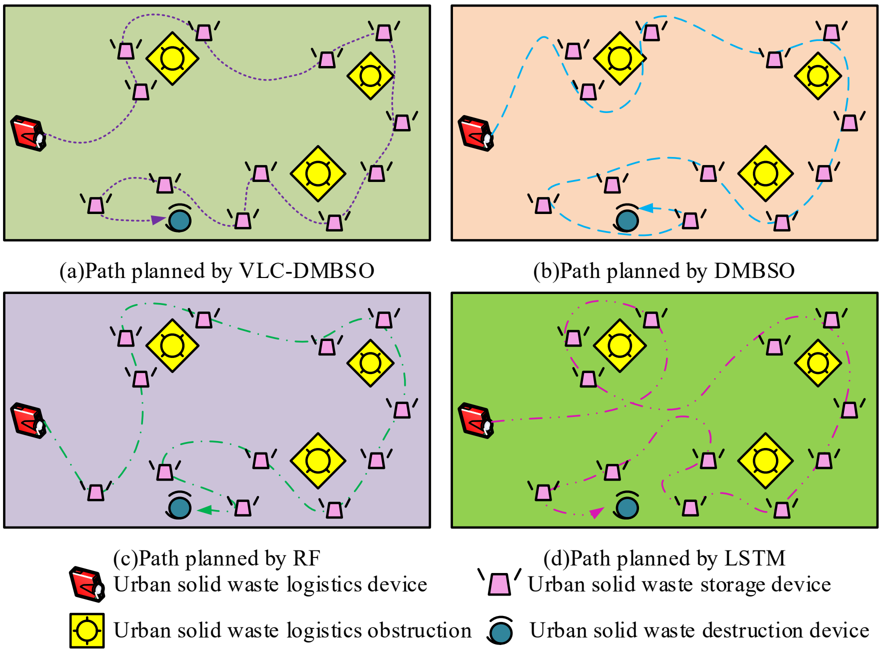

Fig. 7. Path planning results of four models in cities

From Fig. 7, it can be seen that in the path planning experiment of four algorithms for urban solid waste logistics devices, they can all avoid obstacles and make the movement trajectory of the logistics device traverse the solid waste collection device. This indicates that the four algorithms were practical in urban solid waste logistics, but research suggests that there was a lack of evidence to determine the superiority of the four algorithms based on this. Therefore, this study calculated the distance of the planned path and the total carbon emissions during the operation of the solid waste logistics device and plotted the comparison results as shown in Fig. 8.

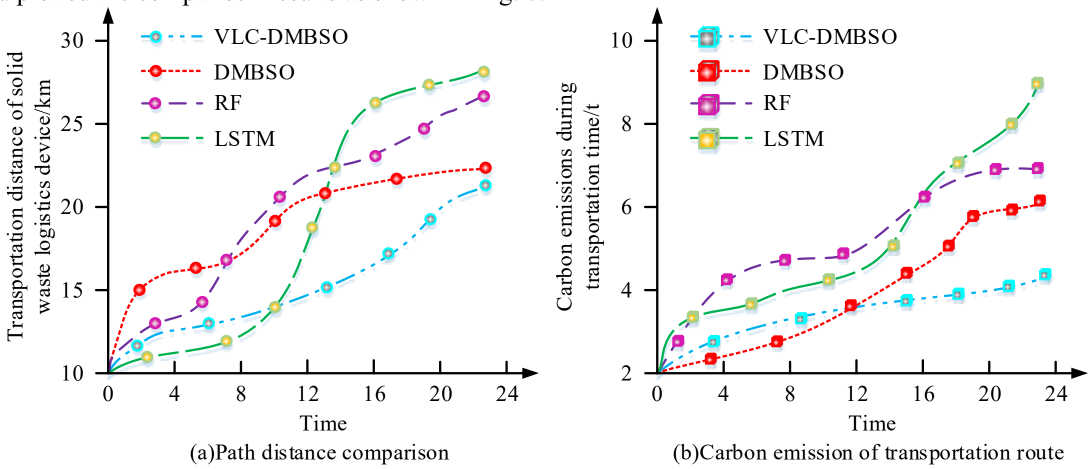

Fig. 8. Comparison of the length of planning path and carbon emissions by four algorithms in one day

Fig. 8 is a comparison of the paths planned by four algorithms to study the transportation length and total carbon emissions of selected logistics devices within a day. From Fig. 8(a), it can be seen that after a day of transportation, the total motion distance of the VLC-DMBSO model was the shortest, at 22 km. The transportation distances of DMBSO, RF, and LSTM were 23, 26, and 27 kilometers, respectively. This fusion algorithm not only had the shortest transportation distance but also performed superior in terms of total carbon emissions. As shown in Fig. 8(b), the daily carbon emissions of the four models were 3.9, 6.0, 6.8, and 8.9 tons, respectively. The path planned by the VLC-DMBSO model performed optimally under the same conditions. In order to make the experimental results universal, the study tested the application of VLC-DMBSO and DMBSO for path planning within 25 days and plotted the carbon emissions of the two models as shown in Fig. 9.

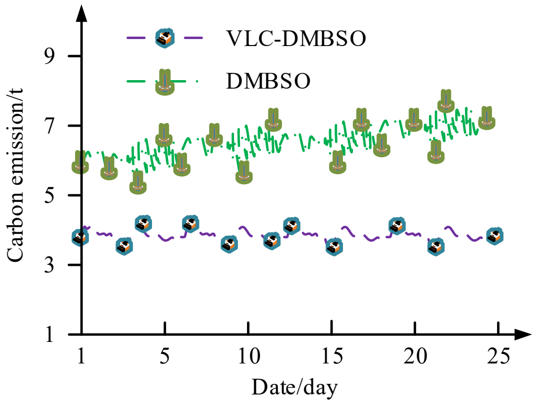

Fig. 9. Carbon emission of VLC-DMBSO and DMBSO in 25 days

From the experimental results in Fig. 9, it can be seen that the carbon emissions of the VLC-DMBSO model approach 4 t within 25 days, with an average of 3.93 t. The carbon emissions of DMBSO fluctuated greatly, with a value within 6.05 ± 0.83 t, and its average value was 6.33 t. The fusion algorithm proposed in the study was more in line with the low-carbon economy for the management of solid waste logistics in cities with the same urban area.

5. Discussion

Effective logistics management of municipal solid waste (MSW) is a method to reduce carbon emissions. Conventional algorithms have some problems in this application, such as low convergence speed and easy to fall into local optimization. Therefore, the VLC-DMBSO algorithm is proposed in this study. In order to verify the effectiveness and universality of the algorithm, the experimental results are compared with the DMBSO algorithm, RF algorithm, and LSTM. After setting the experimental parameters, the F1 values of the four models were 46%, 56%, 62%, and 74% respectively. The loss rates of the four models were 0.04, 0.12, 0.20, and 0.26, respectively, which showed that the performance of the fusion algorithm was better than the other three algorithms. In the practical application of the algorithm, the city was divided into 12 regions equally, and four models were used for path planning. The total movement distance of the proposed model was the shortest, which was 22km, and the carbon emission of the model in one day was 3.9t, which showed that the path planned by VLC-DMBSO not only had the lowest energy consumption but also had excellent carbon emission optimization performance. In order to verify the universality of the algorithm, thirty experiments were carried out in the same city. The linear fitting degrees of VLC-DMBSO and DMBSO models were 0.9964 and 0.9743, respectively. To sum up, the proposed fusion model has superior economic performance and robustness in the logistics management of municipal solid waste, and can effectively reduce the carbon emissions brought by municipal solid waste. However, this study is only aimed at the same city, and the solid waste logistics management between different cities is slightly insufficient, which is also the next direction of the study.

6. Conclusion

With the modernization of science, there has been a sharp increase in urban solid waste, and algorithms that consider the low-carbon economy in waste transportation have been developed. This study considers the low-carbon economy based on DMBSO and adds mutation operators to the optimized algorithm (LC-DMBSO) to generate a fusion algorithm (VLC-DMBSO). The contribution of the research is to ease the tight garbage logistics track and accelerate the transportation speed of urban solid waste. The purpose is to reduce the carbon emission of urban solid waste logistics and then alleviate the greenhouse effect. As for the logistics management of solid waste between different cities, as pointed out by the research goal, the research is only carried out in the same city, and it is expected that the research will be carried out in different cities in the future. Through model testing, it was determined that the number of iterations was set to 62. At this time, the F1 values of VLC-DMBSO, DMBSO, RF, and LSTM were 46%, 56%, 62%, and 74%, respectively. The loss rates of the four models were 0.04, 0.12, 0.20, and 0.26, respectively. When the number of iterations was 62, the performance of the fusion algorithm was superior to the other three algorithms. In the practical application of the algorithm, the study divided cities equally into 12 regions and used four models for path planning. The total motion distance of the proposed model was the shortest, at 22 km, and the transportation distances of the other three models were 23, 26, and 27 km, respectively. The carbon emissions of the four models in one day were 3.9, 6.0, 6.8, and 8.9 tons, respectively, indicating that through the VLC-DMBSO planned path, the energy consumption of the urban solid waste logistics transportation device was not only the lowest but also the optimization performance of carbon emissions was superior. To verify the universality of the algorithm, a graph of experimental results was drawn based on 25 experiments conducted in the same city. The average carbon emissions of the VLC-DMBSO model were 3.93 t. The average carbon emissions of DMBSO were 6.33t. The experimental results indicate that the application of the VLC-DMBSO algorithm is not only suitable for the low-carbon economy but also can bring a better experience for urban solid waste logistics management. However, the method used in this study is only aimed at reducing carbon emissions, and the significance of carbon neutrality is equally important. This is because carbon neutrality research belongs to industry privacy and cannot be obtained. As the number of volunteers increases, this study will continue in the future.

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