Mixed Distribution of Relief Materials with the Consideration of Demand Matching Degree

Ling Gai[1], Ying Jin[1], and Binyuan Zhang[2](✉)

[1] School of Management, Shanghai University, Shanghai 200444, China
{lgai,jinying612}@shu.edu.cn
[2] Renji Hospital Affiliated to Shanghai Jiaotong University, Shanghai 200127, China
Zhangbinyuan2020@163.com

Abstract. Timely and effective distribution of relief materials is one of the most important aspects when fighting with a natural or a man-made disaster. Due to the sudden and urgent nature of most disasters, it is hard to make the exact prediction and projection on the demand information. Meanwhile, timely delivery is also a problem. In this paper, we take the war against COVID-19 as an introductive example, analyze the process of material distribution hosted by a government department. We first show a fuzzy decision-making method to proper evaluate the demand degree of each hospital, then based on the result of it, we propose a mixed distribution model to improve the efficiency of delivery. Finally, we carry on a numerical experiment and compare results with the original way that adopted by the government.

Keywords: COVID-19 · Relief materials · COPRAS · Interval 2-tuple linguistic variable · Mixed distribution

1 Introduction

At the end of 2019, the emergence of 2019 novel coronavirus (COVID-19) in Wuhan, China, has caused a large global outbreak and a major public health issue. As of March 9, 2020, 80890 people have been confirmed being infected by COVID-19 in China. Wuhan, the region of epidemic, has 49448 people infected, accounting for 61% of total infected people in China and 73% of total infected people in Hubei province. As the main rescue force, hospitals need a variety of materials to support their rescue work. However, as the number of confirmed cases increased, the demand for materials is also increasing rapidly. The consumption of various materials in each hospital is very large and many hospitals are under the threat of shortage of materials in the early days of the epidemic.

In Wuhan, there is a government department- the Red Cross, being responsible for the distribution of donated relief materials. The relief materials can be mainly sorted into three types: daily necessities, drug medical material and protection medical material.

Research supported by NSFC (11201333).

Z. Zhang et al. (Eds.): AAIM 2020, LNCS 12290, pp. 627–638, 2020.
https://doi.org/10.1007/978-3-030-57602-8_56

However, the demand of these consumable materials is hard to predict or control, which makes its distribution being a severe problem in the reality.

Currently, the process of distribution hosted by government can be roughly divided into 2 stages. Firstly, each hospital reports their demand for materials, then, these materials are distributed from one single supple depot to each hospital. There are mainly three problems in the process of whole distribution:

a. Due to the situation of each hospital varies every day, government often fails to make an accurate prediction. Virtual high demand reported by hospitals and unfair allocation often happen.
b. The work efficiency of single supple depot is low.
c. In the stage of distribution, each hospital is served by one vehicle (belongs to the hospital or the supple depot). Most of the time vehicles are not fully loaded, which leads to an inefficient delivery. Furthermore, time and manpower are wasted during the whole process.

In order to solve the above problems, this paper puts forward an integrated method from two aspects. We first extend a multi-criteria decision-making method called COPRAS (COmplex PRoportional ASsessment) to evaluate the demand degree of each kind of materials for each hospital respectively. As we mentioned before, decision makers in government often fail to predict the demand of each hospital because the situation of each hospital is varied every day and cannot be counted precisely. Therefore, in this paper, a fuzzy approach is adopted instead of using precise number. We use interval 2-tuple linguistic variables as the evaluation language.

Then, based on the demand degree evaluated before, we prorate each kind of material to each hospital and take this result as the demand of each kind of material for each hospital. Finally, we propose a mixed distribution model to ensure that the relief materials are efficiently distributed.

The rest of this paper is organized as follows: Sect. 2 briefly reviews the literatures related to our problem. In Sect. 3, an extended COPRAS approach is proposed to evaluate the demand degree of each kind of material to each hospital. Section 4 models the distribution of materials and gives its mathematical formulation. Section 5 gives a numerical experiment for the whole process of distribution with 3 kinds of materials and 4 hospitals. Section 6 gives the conclusion of this paper.

2 Literature Review

We now review the literatures related to our problem. As a method of multi-criteria decision-making problem, COPRAS was first proposed by Zavadskas et al. [1] in 1994. They used this method to evaluate the building life cycles in order to select an optimal alternative. After that, many literatures have applied it to some multi-criteria decision-making problems. For instance, Mulliner et al. [2] used it to make an assessment of sustainable housing affordability. Kaklauskas et al. [3] used this method to choose the best option to design an efficient building refurbishment. Mulliner et al. [4] used the COPRAS method for the evaluation of sustainable housing affordability and compared it with other multi-criteria decision-making problem approaches. Pitchipoo et al. [5]

implemented the COPRAS decision-making model to find the optimal blind spot in heavy vehicles. Then, Peng et al. [6] extended the COPRAS method into Pythagorean fuzzy environment, which enriches the abundance of the COPRAS method. Zheng et al. [7] made a severity assessment of chronic obstructive pulmonary disease based on hesitant fuzzy linguistic COPRAS method. This paper combines the COPRAS method with interval 2-tuple linguistic to make an evaluation of each hospital's demand degree.

The literatures for distribution of materials can essentially be classified as two main situations: the demand value of each demand point is known and the demand value of each demand is a decision variable. The first situation is often described as vehicle routing problem (VRP) like reference [8–10] and the second is often described as inventory routing problem (IRP). Coelho [11] has made a comprehensive review for IRP, readers can search it if interested. Based on the number of depots, both of these two problems have been extended with VRP with multiple depots and IRP with multiple depots. For example, Zhen et al. [12] formulated the problem of the last mile distribution in electronic commerce as a multi-depot vehicle routing problem and solved some large-scale instances. Soeanu et al. [13] described the distribution in a supply chain management with the consideration of the risk of vehicle breakdown as a multi-depot vehicle routing problem. Multi-depot inventory was just proposed by Bertazzi et al. [14] in 2019, they described the problem of optimizing supply chain as a multi-depot inventory routing problem.

In summary, VRP tends to minimize the travel cost by determining the set of routes to deliver a given quantity to each customer in a single time period. IRP aims to minimize the routing cost only or the sum of inventory and routing costs over a time horizon by determining the quantity to each customer at each time period and the sets of routes at each time period [14]. This paper also describes the distribution of relief materials as a single-depot routing problem, but still has two differences with previous literatures: we additionally consider the consumption of vehicles and the coordination between vehicles.

3 Extended COPRAS for Evaluation of the Demand Degree

In the process of evaluation, in order to prevent the virtual high demand being reported by hospitals, the evaluation needs to be rated by experts from government. Meanwhile, experts from hospitals are also needed for improving the accuracy of the evaluation, because they often have a better understanding of the situation in hospitals. Therefore, the set of experts responsible for the evaluation should be composed of experts from hospitals and the government. It is usual that experts from different departments tend to use different linguistic term sets to express their judgments on criteria, and sometimes the experts may make a judgment between two linguistic terms for the uncertainty situation of each hospital. For example, there are 2 experts from different departments. Linguistic terms sets used by them and their ratings for a same criterion are respectively shown in Fig. 1 and Fig. 2.

Similar examples cannot be solved by normal fuzzy number like triangular fuzzy number, but it can be well handled by interval 2-tuple linguistic variables [15, 16]. Besides, compared to other fuzzy variables, interval 2-tuple linguistic variables have following advantages: (a) It improves the link between linguistic variables and numerical values. (b) The computational processes of dealing with interval 2-tuple linguistic

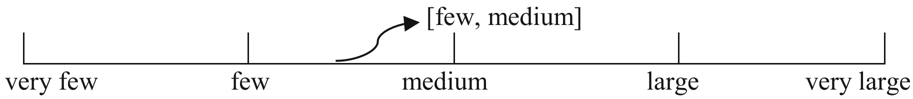

Fig. 1. The linguistic term set and rating of the first expert

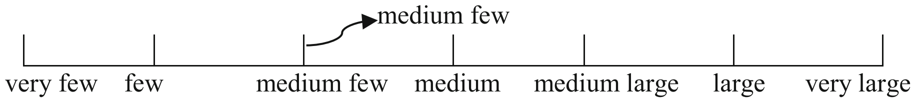

Fig. 2. The linguistic term set and rating of the second expert

variables can avoid loses of information [17]. Therefore, interval 2-tuple linguistic variable is a suitable fuzzy variable for our evaluation. More specific definitions of it are presented in Appendix 1.

The COPRAS is a method of multi-criteria decision-making problems. Compared with other multi criteria decision making methods like TOPSIS, TODIM, it is simple and efficiency, besides, it can process the information when both positive criteria and negative criteria exist [7]. And in our evaluation, criteria like the number of patients have a positive relationship with the demand degree; criteria like the materials inventory level have a negative relationship with the demand degree. Therefore, the COPRAS is an appropriate way for the evaluation of each hospital's demand degree. Finally, this paper uses the COPRAS method based on interval 2-tuple linguistic variable to evaluate each hospital's demand degree for different kind of materials respectively.

Suppose that the Evaluation has H decision makers $DM_h(h = 1, 2, .., H)$, P hospitals $A_p(p = 1, 2, .., P)$, Q criteria $C_q(q = 1, 2, \ldots, Q)$ and B kind of materials $(b = 1, 2, \ldots, B)$. Each decision maker DM_h is given a weight $\lambda_h > 0$ satisfying $\sum_{h=1}^{H} \lambda_h = 1$ to reflect the importance of each decision maker. Let $S = \{s_0, s_1, \ldots, s_g\}$ be the linguistic term set, $D_h = (d_{pq}^h)_{P \times Q}$ be the linguistic decision matrix of decision maker h, where d_{pq}^h is the linguistic information provided by DM_h on the assessment of criteria q for hospital p. Let $\omega_{hb} = \left(\omega_1^{hb}, \omega_2^{hb}, \ldots, \omega_Q^{hb}\right)$ be the linguistic weight vector given by the decision maker h, where ω_q^{hb} is the weight of criteria q under the evaluation for material b provided by DM_h. It is noteworthy that different decision makers can employ different linguistic term set. Based upon assumptions and notations, the procedure of interval 2-tuple linguistic COPRAS method for evaluation of material b's demand degree for each hospital can be defined as follows:

Step 1: Convert the linguistic decision matrix D_h into interval 2-tuple linguistic decision matrix $R_h = \left(\left[\left(r_{pq}^h, 0\right), \left(t_{pq}^h, 0\right)\right]\right)_{P \times Q}$, where $r_{pq}^h, t_{pq}^h \epsilon S$, and $r_{pq}^h \le t_{pq}^h$.
Step 2: Convert the linguistic weight vector ω_{hb} into 2-tuple linguistic weight vector $w_{hb} = \left[\left(w_1^{hb}, 0\right), \left(w_2^{hb}, 0\right), \ldots \left(w_Q^{hb}, 0\right)\right]^T$, where $w_q^{hb} \epsilon S$.

Step 3: Convert each element in the above two interval 2-tuple linguistic decision matrix to its equivalent numerical value with the reverse function Δ^{-1} and the new matrix are separately written as R'_h and w'_h.
Step 4: Aggregate the all decision makers' ratings on each criterion to construct a collective interval 2-tuple linguistic decision matrix $R' = \left(r'\right)_{P\times Q}$, where

$$r' = [\sum\nolimits_{h=1}^{H} \lambda_h \Delta^{-1}\left(r_{pq}^h, 0\right), \sum\nolimits_{h=1}^{H} \lambda_h \Delta^{-1}\left(t_{pq}^h, 0\right), p = 1, 2, \ldots, P,\ q = 1, 2, \ldots, Q \tag{1}$$

Step 5: Aggregate the all decision makers ratings on each criteria weights to construct a collective interval 2-tuple linguistic decision matrix $w' = \left[(w_{1b}, 0), (w_{2b}, 0), \ldots, \left(w_{Qb}, 0\right)\right]^T$, where

$$\left(w_{qb}, 0\right) = (\sum\nolimits_{h=1}^{H} \lambda_h \Delta^{-1}\left(w_q^{hb}, 0\right)), q = 1, 2, \ldots, Q. \tag{2}$$

Step 6: Defuzzy the interval by the following equation:

$$\Delta^{-1}\left[\left(r_{pq}^h, 0\right), \left(t_{pq}^h, 0\right)\right] = [\beta_1, \beta_2] = \frac{\beta_1 + \beta_2}{2} \tag{3}$$

the final collective decision matrix is written as $R'' = \left[r''_{pq}\right]_{P\times Q}$, the final collective weight vector is written as $w'' = \left[w''_{1b}, w''_{2b}, \ldots, w''_{Qb}\right]^T$.
Step 7: Let $E = [e_{pq}]_{P\times Q}$ be the Normalization matrix of the decision-making, where

$$e_{pq} = \frac{w''_q}{\sum_{p=1}^{P} r''_{pq}} r''_{pq} \tag{4}$$

Step 8: Calculate the sums of weighted normalized criteria for every hospital. The criteria are always composed of positive criteria and negative criteria, the higher the positive criteria's values are, the more demand degree of hospital is. Reversely, the higher the negative criteria's values are, the more demand degree of hospital is. The sums of positive and negative weighted normalized criteria are calculated by the following equation:

$$S_p^+ = \sum\nolimits_{z_q} = +e_{pq} \tag{5}$$

$$S_p^- = \sum\nolimits_{z_q} = -e_{pq} \tag{6}$$

where $z_q = \begin{cases} +,\ if\ \ criteria\ q\ is\ positive \\ -,\ if\ \ criteria\ q\ is\ negative \end{cases}$
Step 9: Calculate the relative significance Q_p of each hospital by the following equation:

$$Q_p = S_p^+ + \frac{S_{min}^- \sum_{p=1}^{P} S_p^-}{S_p^- \sum_{p=1}^{P} \frac{S_{min}^-}{S_p^-}} \tag{7}$$

Step 10: Calculate the normalization number $Q_p^{\sim}$ by the following equation,

$$Q_p^{\sim} = \frac{Q_p}{\sum_{p=1}^{P} Q_p} \tag{8}$$

This section proposes a COPRAS method based on 2-tuple linguistic variable for the evaluation of each hospital's demand degree for each kind of material. On the basis of it, we solve the problem unfair allocation and inefficient delivery in next section.

4 Mixed Distribution of the Relief Materials

The following subsections will introduce our model for the distribution of relief materials. In order to match the quantity of each kind of material allocated to each hospital with the demand degree of the hospital, we first prorate each kind of material to each hospital on the basis of the demand degree evaluated in Sect. 3 and take the results as the demand of each hospital. Then we propose a distribution model to improve the efficiency in the process of distribution. We make some assumptions for this distribution model as follows:

a) The definition of unit quantity refers to each undetachable package, so the number of each material means the number of undetachable package of each kind of material;
b) The volume of each package is same;
c) All the vehicles are homogenous and have a same capacity;
d) We consider the number of supple depot is single in our model. Actually, as we mentioned in introduction, the working efficiency of single supple depot is low when the number of relief materials is large. Therefore, multiple supple depots should be set up in face of a large number of materials. And for each supple depot, our model is suitable;
e) Each hospital can be served by multiple vehicles;
f) Vehicles must come back to the supple depot that they leave;
g) The distribution time of each vehicle refers to the total time required for each vehicle to start from the warehouse, visit some hospitals in a certain order, and finally return to the supple depot;
h) The objective is to minimize the sum of all vehicle distribution time, under the precondition that the demand of each hospital is satisfied.

4.1 Basic Notations

To avoid confusion with the notations in previous sections, we claim that the notations used in Sect. 3 are not suitable in Sect. 4 and 5.

Sets

$P = \{0\}$: The set of supple depot
$I = \{1, 2, \ldots, I\}$: The set of hospitals

$V = P \cup I$: The set of supple depots and hospitals
$R = \{1, 2, \ldots, r, \ldots, R\}$: The type of materials
$K = \{1, 2, \ldots, k, \ldots K\}$: The set of homogeneous vehicles
$E = \{(i, j)|i, j \in V, i \neq j\}$: The set of edges between i and j

Parameters

C: The capacity of each vehicle
w_{ir}: The demand degree of hospital i for material r calculated in Sect. 3
t_{ij}: The travel time between hospital i and j
B_r: The number of material r in supple depot

Decision Variables

q_{ir}^k: The number of material r to hospital i delivered from supple depot by vehicle k
z_{ir}^k: 1 if hospital i is served by vehicle k with material r, 0 otherwise
l_{ij}^k: 1 if hospital i is visited before hospital j by vehicle k, 0 otherwise
y_k : 1 if vehicle k is used, 0 otherwise
Q_{ir}: The demand of material r for hospital i

4.2 Mixed Distribution Model

Mathematical formulation of our model can be written as follows:

$$min \sum\nolimits_{k=1}^{K} \sum\nolimits_{i=1}^{V} \sum\nolimits_{j=1}^{V} l_{ij}^k t_{ij} z_{ir}^{kp} \quad (9)$$

The objective function (9) minimizes the sum of all vehicle distribution time. Compared with traditional vehicle routing problem, our objective function takes vehicle consumption into account by using a binary variable y_k. In traditional vehicle routing problem, they often consume all the given vehicles and give a solution of vehicle routing, but don't have to consider the number of used vehicles. Moreover, the constraint that a demand point can only be visited once often lead to the result that each vehicle may finish its task with a relatively high no-load rate and waste of vehicle resources. During the background of epidemic, the government should not only give a solution of vehicle routing which aims to reduce the cost time for delivery, but also should reduce the movement of people to control the spread of the virus and this principle also works for those drivers of vehicles. Besides, hospitals have been filled with patients who get COVID-19 infected and all of them are badly in need of materials, tasks for material delivery are very heavy and it may result the number of vehicles is not enough. Hence, taking the consumption of vehicles into consideration is necessary.

Constraints of this model are presented in Eq. (10)–(15):

$$Q_{ir} = w_{ir} B_r \quad (10)$$

$$Q_{ir} = \sum\nolimits_{k=1}^{K} q_{ir}^{k} \tag{11}$$

$$\sum\nolimits_{r=1}^{R} \sum\nolimits_{i=1}^{I} q_{ir}^{k} z_{ir}^{k} \leq C, \forall k \in K \tag{12}$$

$$\sum\nolimits_{k=1}^{K} y_k \leq K \tag{13}$$

$$\sum\nolimits_{i=1}^{I} z_{ir}^{k} \leq 1, \forall k \in K \tag{14}$$

$$\sum\nolimits_{j=1}^{I} l_{ij}^{k} - l_{ji}^{k} = 0, \forall k \in K, i = 0 \tag{15}$$

Constraint (10) prorates each kind of material to each hospital. Constraint (11) shows the demand of each kind of material r for each hospital should be satisfied by a certain number of vehicles. Constraint (12) shows the capacity limitation of each vehicle. Constraint (13) shows the resource limitation of vehicles. Constraint (14) ensures a vehicle will visit a hospital not more than once. Constraint (15) ensures vehicles come back to the supple depot that they leave.

5 Numerical Experiment

This section examines the formulated problem using numerical example. Firstly, this paper evaluates the demand degree of three typical relief materials for four hospitals in Wuchang District, Wuhan, China. Then we give the result of mixed distribution model.

5.1 Evaluation of the Demand Degree

This paper chooses four hospitals in Wuchang District, Wuhan City, which are shortly named as A_1, A_2, A_3, A_4. An expert committee composed of four decision makers,DM_1, DM_2, DM_3, DM_4, has been formed to evaluate each hospital's demand degree for each kind of material. And DM_1, DM_2 are from hospitals, DM_3, DM_4 are from government. The evaluation is made on the basis of the following four criteria:

(1) The number of hospitalizations who get COVID-19 infected every day.
(2) The proportion of critical patients who get COVID-19 every day.
(3) The overall protection level of hospital.
(4) The inventory level of corresponding materials for COVID-19 every day.

The four decision makers employ different linguistic term sets to make evaluation. Then they give their assessments of four hospitals on each criterion and the weight of each criterion for different materials. It is noteworthy that for different kind of materials, the weight of each criterion given by each expert is also varied. Finally, we use the proposed ITL-COPRAS method to calculate the demand degree of hospitals for different materials. Specific steps of solution are shown in Appendix 2. The demand degree for materials of four hospitals is shown in Table 1.

Table 1. The demand degree of each kind of material for each hospital

Hospital, i	The demand degree of hospital i for material r, w_{ir}		
	1	2	3
1	0.280	0.260	0.267
2	0.189	0.142	0.161
3	0.229	0.186	0.203
4	0.302	0.413	0.369

5.2 Computational Study for Mixed Distribution Model

In this section, we virtually set the number of three kinds of materials in the supple depot and give a numerical experiment for this model. More relative parameters are specifically shown in Appendix 3.

The results of this instance are shown in Tables 2, 3, 4 and 5, the format of Tables 2, 3, 4 and 5 is as follows: Table 2 shows the demand of each kind of material for each hospital. Table 3 and Table 4 respectively show the results of distribution by using our model and the original way. Table 5 is an example of the situation of materials in vehicle 1.

Table 2. Demand of material r for hospital i, Q_{ir}

Hospital, i	The demand degree of hospital i for material r, w_{ir}			The demand of material r for hospital i, Q_{ir}		
	1	2	3	1	2	3
1	0.280	0.260	0.267	9	9	9
2	0.189	0.142	0.161	6	5	6
3	0.229	0.186	0.203	7	6	7
4	0.302	0.413	0.369	10	14	13

From Table 2, we can see that a hospital's demand degree is varied for different kinds of materials and hospitals with higher demand degree can get more materials in general. Take the allocation for hospital 4 as an example. Hospital 4 is a mobile cabin hospital which aims to isolate and give some simple medical treatment for those COVID-19 patients with mild clinical symptom. There are two main characteristics of this hospital: the number of patients is much larger than those general designated hospitals and the clinical symptom of these COVID-19 patients is much milder than those designated hospitals. So it is reasonable that the demand of hospital 4 for daily necessities and drug medical material are the highest. As for the demand of hospital 4 for protection medical

Table 3. The routes of each vehicle and distribution time by using our model

Vehicle, k	y_k	Route	Distribution time (/min)	Total distribution time (/min)
1	1	$0 \rightarrow 1 \rightarrow 2 \rightarrow 0$	18	
2	1	$0 \rightarrow 4 \rightarrow 0$	24	82
3	1	$0 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 0$	40	

Table 4. The routes of each vehicle and distribution time by using the original way

Vehicle, k	y_k	Route	Distribution time (/min)	Total distribution time (/min)
1	1	$0 \rightarrow 1 \rightarrow 0$	10	
2	1	$0 \rightarrow 2 \rightarrow 0$	14	
3	1	$0 \rightarrow 3 \rightarrow 0$	22	94
4	1	$0 \rightarrow 4 \rightarrow 0$	24	
5	1	$0 \rightarrow 4 \rightarrow 0$	24	

Table 5. The number of each kind of material to each hospital in vehicle 1 in our model

Materials, r	Hospitals, i			
	1	2	3	4
1	9	6	0	0
2	9	2	0	0
3	9	0	0	0

material is also the most, this phenomenon relates to the reason that the inventory level of this kind of material for newly-built hospital 4 is much lower than other hospitals.

Table 3 and Table 4 are the result of vehicle routing by using our model and original way respectively. According to the previous government's way of distribution which is shown in Table 3, each vehicle was assigned to deliver to one hospital at a time but without any programming. In our model, for the purpose of improving the efficiency of distribution, we project the driving path of used vehicles which aims to minimize the distribution time of all used vehicles. Obviously, the total cost time for distribution in our model is less than that of the original way.

From Table 5, we can see that all kinds of materials are mixed in vehicle 1 and we still give a solution about the task assignment of each vehicle for each hospital. Take the distribution for hospital 4 as an example, the demand of each kind of material for hospital 4 is satisfied by 2 vehicles, the combination of materials in each vehicle is different and the route of each vehicle is also different. In another word, the distribution of materials for hospital 4 is finished by the coordination of these vehicles with a variety number of materials. In traditional vehicle routing problem or inventory routing problem, the service for a hospital is usually satisfied by a single vehicle and can often lead to the waste of vehicles.

In general, compared with the previous methods adopted currently, our model ensures the fairness of material distribution and improves the efficiency. Moreover, we reduce the number of vehicles used.

6 Conclusions

This paper proposed an integrated method for the distribution of relief materials when facing at an emergency situation. Taking the COVID-19 rescue work as an introductory example, we first compute the demand degree of each hospital for each kind of relief material by COPRAS. Based on the degrees, make the decisions of distribution. Different from classical transportation problem and vehicle routing problem, we consider the consumption of vehicles into accountant, each hospital can be served by different vehicles, and each vehicle may just satisfy parts of the hospital's demand. The results suggest that our evaluation for the demand degree of each hospital for each kind of relief material is actually feasible and reasonable. For the distribution of various emergency relieves, our approach with mixed distribution is effective in reducing the use of vehicles.

References

1. Bergmann, F.M., Wagner, S.M., Winkenbach, M.: Integrating first-mile pickup and last-mile delivery on shared vehicle routes for efficient urban e-commerce distribution. Transp. Res. Part B: Methodol. **131**, 26–62 (2020)
2. Bertazzi, L., Coelho, L.C., Maio, A.D., Laganà, D.: A matheuristic algorithm for the multi-depot inventory routing problem. Transp. Res. Part E: Logist. Transp. Rev. **122**, 524–544 (2019)
3. Chen, C.T., Tai, W.S.: Measuring the intellectual capital performance based on 2-tuple fuzzy linguistic information. In: Proceedings of the 10th Annual Meeting of Asia Pacific Region of Decision Sciences Institute, Taiwan (2005)
4. Coelho, L.C., Cordeau, J.F., Laporte, G.: Thirty years of inventory routing. Transp. Sci. **48**(1), 1–19 (2014)
5. Herrera, F., Martínez, L.: A 2-tuple fuzzy linguistic representation model for computing with words. IEEE Trans. Fuzzy Syst. **8**(6), 746–752 (2000)
6. Hornstra, R.P., Silva, A., Roodbergen, K.J., Coelho, L.C.: The vehicle routing problem with simultaneous pickup and delivery and handling costs. Comput. Oper. Res. **115**. https://doi.org/10.1016/j.cor.2019.104858
7. Kaklauskas, A., Zavadskas, E.K., Raslanas, S.: Multivariant design and multiple criteria analysis of building refurbishments. Energy Build. **37**, 361–372 (2005)
8. Liu, G., Hu, J., Yang, Y., Xia, S., Lim, M.K.: Vehicle routing problem in cold chain logistics: a joint distribution model with carbon trading mechanisms. Resour. Conserv. Recycl. https://doi.org/10.1016/j.resconrec.2020.104715
9. Mulliner, E., Smallbone, K., Maliene, V.: An assessment of sustainable housing affordability using a multiple criteria. Omega **41**, 270–279 (2013)

10. Mulliner, E., Malys, N., Maliene, V.: Comparative analysis of MCDM methods for the assessment of sustainable housing affordability. Omega **59**, 146–156 (2016)
11. Peng, X., Selvachandran, G.: Pythagorean fuzzy set: state of the art and future directions. Artif. Intell. Rev. **52**(3), 1873–1927 (2017)
12. Pitchipoo, P., Vincent, D.S., Rajini, N., Rajakarunakaran, S.: COPRAS decision model to optimize blind spot in heavy vehicles: a comparative perspective. Procedia Eng. **97**, 1049–1059 (2014)
13. Soeanu, A., Ray, S., Berger, J., Boukhtouta, A., Debbabi, M.: Multi-depot vehicle routing problem with risk mitigation. Model and solution algorithm. Expert Syst. Appl. **145**, 113099 (2020)
14. You, X.Y., You, J.X., Liu, H.C., Zhen, L.: Group multi-criteria supplier selection using an extended VIKOR method with interval 2-tuple linguistic information. Expert Syst. Appl. **42**(4), 1906–1916 (2015)
15. Zavadskas, E.K., Kaklauskas, A., Sarka, V.: The new method of multi-criteria complex proportional assessment of projects. Technol. Econ. Dev. Econ. **1**(3), 131–139 (1994)
16. Zhang, H.: The multi-attribute group decision making method based on aggregation operators with interval-valued 2-tuple linguistic information. Math. Comput. Model. **56**, 27–35 (2012)
17. Zhen, L., Ma, C., Wang, K., Xiao, L., Zhang, W.: Multi-depot multi-trip vehicle routing problem with time windows and release dates. Transp. Res. Part E: Logist. Transp. Rev. **135**. https://doi.org/10.1016/j.tre.2020.101866