CPO industry supplier selectio model for a multi-objective green supply chain network under uncertainty

by Hardi Mulyono

Results in Nonlinear Analysis 6 (2023) No. 3, 121–129
https://doi.org/10.31838/rna/2023.06.03.012
Available online at www.nonlinear-analysis.com

Results in Nonlinear Analysis
ISSN 2636-7556

Peer Reviewed Scientific Journal

CPO industry supplier selection model for a multi-objective green supply chain network under uncertainty

Parapat Gultom[a], Rizky Habibi[b], Hardi Mulyono[c]

[a]Department of Mathematics, Universitas Sumatera Utara, Medan, Indonesia; [b]Institut Akademi Informatika dan Komputer Medicom, Medan. Indonesia; [c]Univesitas Muslim Nusantara Al-Washliyah, Medan, Indonesia

Abstract

Research to identify optimal suppliers in the CPO industry is becoming increasingly important as technology changes and market globalization. This study proposes a mathematical model for the problem of selecting suppliers for the CPO industry by considering the green factor. Stochastic parameters are also considered to deal with uncertain parameters in green supply chain networks. The objective of this model is to select suppliers taking into account the total costs and total greenhouse gas emissions. Uncertainty in the input is handled by stochastic programming, and the multi-objective model is solved as a single-objective model by the LP-metric method. This paper aims to present a more comprehensive model based on real-world conditions for the supplier selection problem of green supply chain in the CPO industries under uncertainty. Besides economic issues, environmental issues are also considered from several aspects such as selecting environmentally friendly suppliers and purchasing from them and considering the environmental impact of the finished product. The results shows that increasing one of the indicators such as the number of products and market demand leads to an increase in the value of the total objective function, which is caused by an increase in problem size. On the other hand, the cost function increases when the majority of supplier selection is environmentally friendly suppliers. Meanwhile, the function of the objective level of greenhouse gas emissions increases when the selection of suppliers is the majority of suppliers with high greenhouse gas emissions, but the objective function of costs decreases.

Keyword: Suppliers selection, Multi-objective model, Green supply chain networks.

Email addresses: parapat@usu.ac.id (Parapat Gultom); pakhabibi@gmail.com (Rizky Habibi); hardimulyono@umnaw.ac.id (Hardi Mulyono)*

Received July 24, 2023; Accepted August 20, 2023; Online September 14, 2023

1. Introduction

The Indonesian CPO industry has grown significantly in the last forty years. In 2018, the world produced 72 million tonnes of CPO and Indonesia contributed 57% of that amount (41 million tonnes) [1]. The CPO industry has two major challenges originating from the international market, namely environmental issues and market acceptance. Environmental issues have become one of the most important social-commercial issues today. This indicates the need for Green supply chain management (GSCM) to be implemented at various echelons of the CPO industry supply chain. GSCM is directly related to improving economic performance [2], competitiveness and environmental conditions [3]. Various advantages and benefits of green supply chain management in improving supply chain environmental performance include creating value for customers, saving energy resources, eliminating or reducing waste, reducing emissions, and ultimately increasing productivity for the company.

Supplier selection is one of the most important components of the supply chain. Selection of suppliers in the supply chain is a strategic decision that is very important for the success of the organization; therefore, it has attracted the attention of many academic and non-academic researchers [4]. Supplier selection is the process of identifying the most appropriate supplier capable of supplying the required products and services at a reasonable price and in the right quantity and time [5]. Selection of the right supplier requires robust models and analytical tools for decision support systems to enable them to balance multiple objectives and subjective criteria at the same time [6]. Cavinato and Kauffman [7] state that supplier selection issues have a dominating effect on supply chains and procurement processes; in other words, choosing the right supplier is the key to the procurement process.

Considering environmental factors in purchases results in increased net income and decreased costs [8]. Selection of the right supplier reduces the operational costs of the organization and improves the quality of their products in the future; on the other hand, selecting the wrong supplier causes financial and operational problems [9]. This paper aims to present a model for the supplier selection CPO industry problem in the context of GSCM by considering environmental issues from various aspects such as selecting green suppliers and purchasing from them, as well as incorporating the intrinsic uncertainty of the model parameters by using discrete supplier scenarios and stochastic programming.

2. Literature Review

Supplier selection in the CPO industry is a crucial issue that plays a key role in the supply chain. To create a competitive advantage, CPO factories must pay sufficient attention to supplier selection. The main methods used to solve supplier selection problems are classified into three categories such as mathematical models, data envelopment analysis (DEA) methods, and multiple decision making methods. Memon et al. [10] stated that the supplier selection problem involves random uncertainties and used a combination of gray theory and uncertainty theory to solve it. Their research aims to reduce the risk of buying from suppliers.

Hajikhani et al. [11] presented a multi-objective fuzzy model for selecting and allocating orders to suppliers under uncertain conditions, considering multi-period, multi-source and multi-product cases with bi-level prices and supply chains. They provided farm case studies to demonstrate the applicability of their model and solved it with the non-dominance sequencing genetic algorithm (NSGA-II) and the MOPSO algorithm. Mohammaditabar et al. [12] investigated the evaluation of selected suppliers and prices in a decentralized supply chain and the selection of suppliers in a way that would benefit the entire supply chain and used cooperative and non-cooperative game theory methods to assess selected suppliers and total supply chain costs in two scenarios. In the first scenario, the suppliers work independently, while in the second scenario, the suppliers cooperate with each other.

The second type of fuzzy interval data has been used by Heidarzadeh et al. [13] to show the preferences of decision makers and present a new formula to calculate the distance between fuzzy and second interval data. Then, they propose a hierarchical clustering method to solve the supplier selection problem. Amorim et al. [14] provide an integrated framework to reduce the supplier selection process in the food industry under uncertain conditions. They developed a two-stage mixed integer random programming model for supplier selection in the food industry that maximizes profits and minimizes the risk of losing customers. In their model, corruption of raw materials and finished products, uncertainty, and long-term demands have been considered. They apply Bender's method to solve this problem.

Erginel and Gecer [15] discussed calibration of measurement devices as one of the requirements of the ISO 9001 standard for quality through the development of multi-purpose fuzzy models to provide quality at acceptable prices at suppliers of calibration services other than raw materials. and product suppliers. Sodenkamp et al. [16] developed a meta-approach to support cooperative multiobjective supplier selection and order allocation decisions by combining multicriteria decision analysis and linear programming. They propose maximizing the total value of purchases by optimizing the assignment of order quantities to suppliers considering the synergies they face across multiple time horizons. Jains et al. [17] discussed an eco-friendly and carbon market sensitive decision-making approach based on the DEA method and assessed the applicability of their model using a well-known auto parts manufacturer in India. Yousefi et al. [18] used the DEA method for supplier selection. They recognized that although the DEA method determined patterns for inefficient units, they were unable to differentiate between efficient units. To this end, they propose ideal dynamic units using dynamic DEA and scenario-based models and measure their effectiveness with case studies.

Pandey et al. [19] developed a framework for this issue by evaluating suppliers based on quantitative and qualitative data. They propose a two-phase fuzzy objective programming method that incorporates hyperbolic membership functions to solve the supplier selection problem under uncertainty. Lo et.al (2018) [20] proposed a new model that integrates the best-worst method (BWM), a modified fuzzy technique for order preference with similarity to an ideal solution (TOPSIS), and fuzzy multi-objective linear programming (FMOLP) to solving problems in green supplier selection and order allocation. Javad et al. [21] identified the company's alternative suppliers and the most effective supplier selection criteria based on the supplier's green innovation capability were determined. The Best-Worst method is used to rank various criteria for selecting green suppliers in a multi-criteria decision-making problem. Then, Fuzzy TOPSIS is used to rank various suppliers based on weighted criteria to select the most effective supplier among a set of alternative suppliers.

These various studies investigate the problem of supplier selection with different approaches. This paper aims to present a model based on real-world conditions for the problem of selecting CPO suppliers in a green supply chain under uncertainty.

3. Research Methodology

This study develops a multi-objective mathematical model for the problem of selecting CPO mill suppliers in the context of the GSCN. Consists of two objective functions, minimize economic costs; and minimize greenhouse gas emissions. Stochastic programming is used to deal with the demands attached to the input parameters, scenarios are considered for each parameter and to solve the proposed multi-objective mathematical model as a single objective model with the LP-metric method. Then, numerical examples are given to demonstrate the effectiveness model.

3.1 Problem description and mathematical model

In this study, the problem of supplier selection (CPO manufactories) is considered where the Special Economic Zone (SEZ) which processes CPO into finished products sends its products to the demand market after buying CPO from suppliers and producing finished products from CPO. The objective of this study to minimize total costs and reduce environmental impact by selecting and purchasing from environmentally friendly suppliers. The proposed supply chain network is shown in Figure 1.

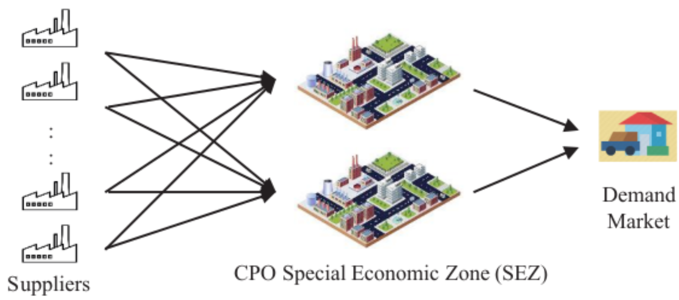

Figure 1: CPO Industry Supply Chain Network.

3.1.1 Assumptions

- Facility locations such as suppliers and SEZ are determined at the beginning;
- The capacity of each facility is known at the beginning;
- The proposed model is considered as a single-product;

3.1.2 Sets

i : Suppliers;

j : SEZ which process CPO into finished products.

3.1.3 Parameters

c_{js} : Production cost per unit of finished products at SEZ j under Scenario s;

a_{is} : Purchase cost per metric ton (MT) of CPO from Supplier i under Scenario s;

l_{ijs} : Transportation cost per MT of CPO between Supplier i and SEZ j under Scenario s;

k_{js} : Transportation cost of finished product between SEZ j and Demand Market under Scenario s;

d_{js} : Disassembly cost per MT of CPO at SEZ j under Scenario s;

h_{js} : Maintenance cost unit of finished products under Scenario s;

n : Percentage of Volume of CPO needed to make 1 MT of finished product;

b_s : Cost of delay in supplying per MT of CPO under Scenario s;

t_s : Fees charged per 1 metric ton by the system in the case of purchasing from green suppliers under Scenario s;

u_{is} : The maximum acceptable level of greenhouse gas emissions by Supplier i under Scenario s according to environmental indicators;

g_{is} : Percentage of total volume of raw materials purchased from Supplier i that are supplied with delays under Scenario s;

e_{is} : Greenhouse gas emissions in Supplier i under Scenario s;

f_{is} : Greenhouse gas emissions per 1 metric ton CPO purchasing from Supplier i under Scenario s;

D_{js} : The amount of Market Demand for finished products at SEZ j in Scenario s;

cap_i : Raw material volume capacity at Supplier i (in metric ton);

p_s : Probability of Scenario s.

3.1.4 Variables

x_{ijs} : Amount of CPO sent by Supplier i to SEZ j under Scenario s;
y_{js} : Amount of finished product unit sent by SEZ j to the demand market under Scenario s;
z_{ij} : 1 if Supplier i is selected by SEZ j to purchase, 0 otherwise;
w_i : 1 if total greenhouse gas emissions from Supplier i still acceptable level, 0 otherwise.

3.1.5 Mathematical model

$$Min\, f_1 = \sum_i \sum_j \sum_s p_s (x_{ijs}(a_{is} + b_s g_{is} + l_{ijs} + d_{js} + (t_s w_i z_{ij}))) + \sum_j \sum_s p_s (h_{js}(y_{js} - D_s) + y_{js}(c_{js} + k_{js})) \quad (1)$$

$$Min\, f_2 = \sum_i \sum_s P_s w_i e_{is} + \sum_i \sum_j \sum_s P_s x_{ijs} f_{is} z_{ij} \quad (2)$$

S.t:

$$\sum_j y_{js} \geq nD_s \quad \forall s \quad (3)$$

$$\sum_j z_{ij} \leq \sum_j x_{ijs} \quad \forall i,s \quad (4)$$

$$\sum_j x_{ijs} \leq \sum_j cap_i z_{ij} \quad \forall i,s \quad (5)$$

$$w_{is} e_{is} \leq u_{is} \quad \forall i,s \quad (6)$$

$$\begin{aligned} & x_{ijs}, y_{js} \geq 0 \\ & z_{ij}, w_i \in \{0,1\} \end{aligned} \quad (7)$$

The objective function (1) minimizes the cost of purchasing raw materials, transportation costs, production costs, disassembly costs, maintenance costs, penalty costs for delays and costs for selecting environmentally friendly suppliers (disregarding distance, contract costs, etc.). The objective function (2) is to reduce supplier greenhouse gas emissions using the max-min method. Constraint (3) states that the product produced is greater than the market demand. Constraint (4) states that if supplier i is selected, there must be a flow of raw materials from supplier i to the factory. Constraint (5) limits supplier capacity. Constraint (6) indicates whether the supplier is environmentally friendly or not. Constraint (7) describes the types of variables.

3.2 Solution approach

Many approaches have been presented in the literature to solve multi-objective model optimization. They can be classified into five main categories, including scalar methods, interactive methods, fuzzy methods, metaheuristic methods and decision aid methods [22]. In this paper, the multi-objective optimization method was chosen because: (1) Based on the judgment of experts, all objective functions are equally important, and (2) objective functions have different sizes. The objective function in this study was not homogeneous and did not have the same size, therefore the LP-metric method was used [23]. If we take q_1 dan q_2 as minimization objective functions, we have:

$$MIN\, Q^*_{total} = \lambda_1 q_1^{norm} + \lambda_2 q_2^{norm} \quad (8)$$

In this method, the normalized values q_1 dan q_2 are the objective minimization functions obtained from the equation:

$$q_i^{norm} = \frac{z_i - z_i^{min}}{z_i^{max} - z_i^{min}} \tag{9}$$

4. Numerical Experimentation

To check the accuracy and efficiency of the proposed model, a test problem is generated for numerical analysis. In the preparation stage of the supply chain, it is assumed that there are two SEZs (j_1 and j_2), ten suppliers (i_1, i_2, i_3, i_4, i_5, i_6, i_7, i_8, i_9, and i_{10}), and one market demand. The uncertainty in the input parameters is considered for two scenarios (scenario-1, scenario-2) with probabilities of 0,4 and 0,6. Percentage volume of CPO needed to make 1 MT of finished product considered $\bar{n}$ = 1,46. This value indicates that to make 1MT of finished product, 1.46 MT of CPO is required. The pairwise transportation cost from each supplier to SEZs (l_{ijs}) are given in Table 1. These parameters l_{ijs} are given with uniform distribution between (15, 30). Production cost (c_{js}), disassembly costs (d_{js}), maintenance costs (h_{js}), and the amount of market demand for finished products (D_{js}) are given in Table 2. These parameter c_{js} are given with uniform distribution between (250,350), d_{js} and h_{js} between (2,8).

The volume capacity of CPO at each supplier in metric ton (cap_i) are given in Table 3. These parameters cap_i are given with uniform Distribution between (300, 1500). Purchase cost CPO per a metric ton (in million rupiah) from each supplier (a_{is}), the maximum acceptable level of greenhouse gas emissions (u_{is}), percentages of total raw materials purchased from each supplier that are supplied with delays (g_{is}), greenhouse gas emissions level from each supplier (e_{is}) and greenhouse gas emissions per

Tabel 1: Transportastion cost, production cost, disassembly costs, maintenance costs per metric ton (in ten thousand rupiah), and the amount of market demand for finished products (metric ton).

		i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}
Scenario-1	j_1	24	17	31	28	18	20	15	21	20	22
	j_2	22	18	21	21	20	19	29	19	23	16
Scenario-2	j_1	25	24	26	21	21	27	17	27	25	22
	j_2	23	22	15	27	17	21	28	16	29	27

Tabel 2: Disassembly costs, maintenance costs per metric ton (in ten thousand rupiah), and the amount of market demand for finished products (metric ton).

		c_{js}	k_{js}	d_{js}	h_{js}	D_{js}
Scenario-1	j_1	282	13	5	2	2500
	j_2	326	11	6	3	1000
Scenario-2	j_1	304	14	5	4	1200
	j_2	315	18	4	5	2000

Tabel 3: Volume capacity of CPO at Supplier i (in metric ton).

	i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}
cap_i	610	1440	1220	570	950	620	380	1080	870	890

1 metric ton CPO purchasing (f_{is}) are given in Table 4. These parameters a_{is} are given with uniform distribution between (500, 700), u_{is} between (100,200), g_{is} between (0.2,0.8), e_{is} between (100,400), and f_{is} between (0.2,0.8). Cost of delay in supplying of CPO per metric ton (b_s), fees charged by the system in the case of purchasing from green suppliers (t_s) are given in Table 5. These parameters b_s are given with uniform distribution between (20, 30), and t_s between (400,500).

Numerical experiments were carried out on a computer with Intel(R) Core(TM) i5-3427U CPU @ 1.80GHz 2.30 GHz with 8 GB RAM. The mathematical model proposed in this paper is solving using solver. Numerical experimental results shown decision result for the number of suppliers in green supply chain network under both scenarios presented in Table 6.

Tabel 4: Purchase cost (in ten thousand rupiah), the maximum acceptable level of greenhouse gas emissions, percentage of raw materials purchased that are supplied with delays, and greenhouse gas emissions from suppliers.

		i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}
Scenario-1	a_{i1}	583	502	563	548	595	539	610	500	617	534
	u_{i1}	168	197	189	180	154	159	175	191	195	151
	g_{i1}	0,46	0,42	0,24	0,55	0,24	0,46	0,59	0,34	0,51	0,48
	e_{i1}	151	377	253	116	288	129	261	160	295	327
	f_{i1}	0,8	0,8	0,3	0,5	0,2	0,8	0,2	0,4	0,5	0,3
Scenario-2	a_{i2}	507	636	575	621	594	569	628	532	538	544
	u_{i2}	185	165	100	108	196	121	173	151	180	185
	g_{i2}	0,57	0,38	0,42	0,38	0,34	0,56	0,54	0,26	0,32	0,37
	e_{i2}	382	117	187	138	132	213	374	326	270	148
	f_{i2}	0,5	0,7	0,4	0,2	0,7	0,8	0,7	0,3	0,4	0,4

Tabel 5: Cost of delay per metric ton of CPO and fees charged of purchasing from green suppliers (in ten thousand rupiah).

	b_s	t_s
Scenario-1	20	500
Scenario-2	30	400

Tabel 6: Decision result for the number of suppliers in green supply chain network under both Scenarios.

Scenarios	SEZs	Demand Market	Environmental Friendly Supplier	Selected Supplier No.	Selected Supplier Supliers i	Objective Functions Obj-1 (in million)	Objective Functions Obj-2
Scenario-1	j_1	2000	1, 4, 6, 8	4	2, 5, 8, 10	45.103	3.239
	j_2	1000		2	3,1		
Scenario-2	j_1	1200	2,5,10	2	5, 10	52.329	1.619
	j_2	2000		3	1,2,3		

The results shown in Table.1 explain the decision in the first scenario shows that among the 4 suppliers that are environmentally friendly (suppliers 1, 4, 6, 8), only 2 suppliers are selected, supplier i_8 which supplies SEZ_1 and supplier i_1 which supplies SEZ_2. It can be seen that the cost can be minimized to IDR 45,103,840,000; with a much higher greenhouse gas emissions level than in the second scenario. In the second scenario, the number of demand market CPO is 2200 MT that must be fulfilled is less than in the first scenario 3000 MT, but the costs incurred are greater than in the first scenario of IDR 52,329,804,000. This happens because in the second scenario, decisions are taken between 3 environmentally friendly suppliers (suppliers 2, 5, 10), there are two suppliers selected, namely suppliers which are i_5 and i_{10} which supply SEZ_1 and SEZ_2 and supplier i_2 which supplies SEZ_2, so this minimizes the level of gas emissions produced to 1619.

5. Conclusion

In this paper, a multi-objective mixed integer programming model is developed for the selection of suppliers in a green supply chain and to get closer to real-world problems, the selection has been selected in the model. In the model presented, supplier selection is proposed to optimally reduce economic costs, and reduce supplier-related greenhouse gas emissions. The mathematical model is solved and the analysis results obtained are carried out using sensitivity analysis. Analysis of the results shows that increasing one of the indicators such as the number of products and market demand leads to an increase in the value of the total objective function, which is caused by an increase in problem size. On the other hand, the cost function increases when the majority of supplier selection is environmentally friendly suppliers. Meanwhile, the function of the objective level of greenhouse gas emissions increases when the selection of suppliers is the majority of suppliers with high greenhouse gas emissions, but the objective function of costs decreases. Lastly, time window concept and inventory in green supply chain can be studied for further research.

References

[1] Ritchie, H., Roser, M., Forests and Deforestation. Published online at OurWorldInData.org., (2021). Retrieved from: https://ourworldindata.org/forests-and-deforestation [Online Resource].

[2] Zhu, Q., Sarkis, J., *Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises*. Journal of Operations Management. 22(3), (2004), 265–289.

[3] Rao, P., Holt, D., *Do green supply chains lead to competitiveness and economic performance?* International Journal of Operations & Production Management, 25(9), (2005), 898–916.

[4] Memon, M.S., Lee, Y.H., Mari, S.I., *Group multi-criteria supplier selection using combined grey systems theory and uncertainty theory*. Expert Systems with Applications, 42(21), (2015), 7951–7959.

[5] De-Boer, L., Labro, E., Morlacchi, P., *A review of methods supporting supplier selection*. European Journal of Purchasing & Supply Management, 7(2), (2001), 75–89.

[6] Bhattacharya, A., Geraghty, J., Young, P., *Supplier selection paradigm: an integrated hierarchical QFD methodology under multiple-criteria environment*. Applied Soft Computing, 10(4), (2010), 1013–1027.

[7] Cavinato, J., Kauffman, R., *The Purchasing Handbook: A Guide for the Purchasing and Supply Professional*, McGraw-Hill, New York, NY, (2000).

[8] Carter, C.R., Kale, R., Grimm, C.M., *Environmental purchasing and firm performance: an empirical investigation*. Transportation Research Part E: Logistics and Transportation Review, 36(3), (2000), 219–228.

[9] Weber, C.A., Current, J.R., Benton, W., *Vendor selection criteria and methods*. European Journal of Operational Research, 50(1), (1991), 2–18.

[10] Memon, M.S., Lee, Y.H., Mari, S.I., *Group multi-criteria supplier selection using combined grey systems theory and uncertainty theory*. Expert Systems with Applications, 42(21), (2015), 7951–7959.

[11] Hajikhani, A., Khalilzadeh, M., Sadjadi, S.J., *A fuzzy multi-objective multi-product supplier selection and order allocation problem in supply chain under coverage and price considerations: an urban agricultural case study*. Scientia Iranica, (2017).

[12] Mohammaditabar, D., Ghodsypour, S.H., Hafezalkotob, A., *A game theoretic analysis in capacity-constrained supplier-selection and cooperation by considering the total supply chain inventory costs*. International Journal of Production Economics, 181, (2016), 87–97.

[13] Heidarzadeh, A., Mahdavi, I., Mahdavi-Amiri, N., *Supplier selection using a clustering method based on a new distance for interval type-2 fuzzy sets: a case study*. Applied Soft Computing, 38, (2016), 213–231.

[14] Amorim, P., Curcio, E., Almada-Lobo, B., Barbosa-P_ovoa, A.P., Grossmann, I.E., *Supplier selection in the processed food industry under uncertainty*. European Journal of Operational Research, 252(3), (2016), 801–814.

[15] Erginel, N., Gecer, A., *Fuzzy multi-objective decision model for calibration supplier selection problem*, Computers & Industrial Engineering, 102, (2016), 166–174.

[16] Sodenkamp, M.A., Tavana, M., Di-Caprio, D., *Modeling synergies in multi-criteria supplier selection and order allocation: an application to commodity trading*. European Journal of Operational Research, 254(3), (2016), 859–874.

[17] Jain, V., Kumar, S., Kumar, A., Chandra, C., *An integrated buyer initiated decision-making process for green supplier selection*. Journal of Manufacturing Systems, 41, (2016), 256–265.

[18] Yousefi, S., Shabanpour, H., Fisher, R., Saen, R.F., *Evaluating and ranking sustainable suppliers by robust dynamic data envelopment analysis*. Measurement, 83, (2016), 72–85.

[19] Pandey, P., Shah, B.J., Gajjar, H., *A fuzzy goal programming approach for selecting sustainable suppliers*. Benchmarking: An International Journal, 24(5), (2017), 1138–1165.

[20] Lo, H., Liou, J.H., Wang, H., Tsai, Y., *An integrated model for solving problems in green supplier selection and order allocation*. Journal of Cleaner Production, 190, (2018), 339–352.

[21] Javad, M.O.M., Darvishi, M., Javad, A.O.M., *Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: A case study of Khouzestan steel company*. Sustainable Futures, 2, (2020), 100012.

[22] Rajabi-Bahaabadi, M., Shariat-Mohaymany, A., Babaei, M. Ahn, C.W., *Multi-objective path finding in stochastic time-dependent road networks using non-dominated sorting genetic algorithm*. Expert Systems with Applications, 42(12), (2015), 5056–5064.

[23] Deb, K., *Multi-Objective Optimization Using Evolutionary Algorithms*. John Wiley & Sons, Hoboken, NJ. (2001).

CPO industry supplier selection model for a multi-objective green supply chain network under uncertainty

ORIGINALITY REPORT

19%	17%	18%	12%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Liu, Chunxia, Tong Shu, Shou Chen, Shouyang Wang, Kin Keung Lai, and Lu Gan. "An improved grey neural network model for predicting transportation disruptions", Expert Systems with Applications, 2016. Publication	1%
2	www.researchgate.net Internet Source	1%
3	www.readbag.com Internet Source	1%
4	Jiménez, Tamara, Noemí Merayo, Anaïs Andrés, Ramón J. Durán, Juan C. Aguado, Ignacio de Miguel, Patricia Fernández, Rubén M. Lorenzo, and Evaristo J. Abril. "An auto-tuning PID control system based on genetic algorithms to provide delay guarantees in Passive Optical Networks", Expert Systems with Applications, 2015. Publication	1%

5	Büşra MENİZ. "An advanced TOPSIS method with new fuzzy metric based on interval type-2 fuzzy sets", Expert Systems with Applications, 2021 Publication	1 %
6	dergipark.org.tr Internet Source	1 %
7	iosrjournals.org Internet Source	1 %
8	www.mdpi.com Internet Source	1 %
9	paulorodrigues.pro.br Internet Source	1 %
10	link.springer.com Internet Source	1 %
11	Babader, Ahmed, Jun Ren, Karl O. Jones, and Jin Wang. "A system dynamics approach for enhancing social behaviours regarding the reuse of packaging", Expert Systems with Applications, 2016. Publication	1 %
12	Submitted to University of Wollongong Student Paper	1 %
13	sic.ici.ro Internet Source	1 %

14	findresearcher.sdu.dk Internet Source	1 %
15	www.leadershipmanagementmagazine.com Internet Source	1 %
16	Mohammad Tavassoli, Reza Farzipoor Saen, Dariush Mohamadi Zanjirani. "Assessing sustainability of suppliers: A novel stochastic-fuzzy DEA model", Sustainable Production and Consumption, 2020 Publication	1 %
17	www.ippa.org Internet Source	1 %
18	Qiang Yang, Zhen-Song Chen, Catherine Y.P. Chan, Witold Pedrycz, Luis Martínez, Mirosław J. Skibniewski. "Large-scale group decision-making for prioritizing engineering characteristics in quality function deployment under comparative linguistic environment", Applied Soft Computing, 2022 Publication	1 %
19	Solmaz Karimi, Godsfavour Umoru, Cynthia El Rahi. "Chapter 3 Leaving No Stone Unturned: Unraveling the Path to Maximizing the Potential for Discovery of Novel Antineoplastics", Springer Science and Business Media LLC, 2023 Publication	1 %

20 www.tandfonline.com
Internet Source
1 %

21 "Informatics Engineering and Information Science", Springer Science and Business Media LLC, 2011
Publication
<1 %

22 www.jseepub.com
Internet Source
<1 %

23 Peiman Ghasemi, Kaveh Khalili-Damghani, Ashkan Hafezalkotob, Sadigh Raissi. "Stochastic optimization model for distribution and evacuation planning (A case study of Tehran earthquake)", Socio-Economic Planning Sciences, 2019
Publication
<1 %

24 Chao Shang, Fan Yang, Biao Huang, Dexian Huang. "Recursive Slow Feature Analysis for Adaptive Monitoring of Industrial Processes", IEEE Transactions on Industrial Electronics, 2018
Publication
<1 %

25 gmd.copernicus.org
Internet Source
<1 %

26 ourworldindata.org
Internet Source
<1 %

27 coek.info
Internet Source

		<1%
28	Abid Haleem, Shahbaz Khan, Sunil Luthra, Harshit Varshney, Musaib Alam, Mohd Imran Khan. "Supplier evaluation in the context of circular economy: A forward step for resilient business and environment concern", Business Strategy and the Environment, 2021 Publication	<1%
29	Matthijs Oyaert, Sander De Bruyne, Christel Van Camp, Inge Van de Caveye, Joris Delanghe. "Lipid droplets may interfere with urinary red blood cell and crystal counts by urinary flow cytometry", Clinical Chemistry and Laboratory Medicine (CCLM), 2023 Publication	<1%
30	Jing-min Wang. "A Simulation-Based Robust Optimization Model for Supply Chain Network Design", 2008 Fourth International Conference on Natural Computation, 10/2008 Publication	<1%
31	ethesis.nitrkl.ac.in Internet Source	<1%
32	onlinelibrary.wiley.com Internet Source	<1%
33	Leyla Fazli. "Supplier selection using improved input efficiency profiling with common set of	<1%

weights model", International Journal of Industrial and Systems Engineering, 2018
Publication

34	Yulin Sun, Simon Cong Guo, Xueping Li. "An order-splitting model for supplier selection and order allocation in a multi-echelon supply chain", Computers & Operations Research, 2021 Publication	<1%
35	ebin.pub Internet Source	<1%
36	hydra.hull.ac.uk Internet Source	<1%
37	Jin Tao, Lusheng Shao, Zhimin Guan, William Ho, Srinivas Talluri. "Incorporating risk aversion and fairness considerations into procurement and distribution decisions in a supply chain", International Journal of Production Research, 2019 Publication	<1%
38	Chai, Junyi, James N.K. Liu, and Eric W.T. Ngai. "Application of decision-making techniques in supplier selection: A systematic review of literature", Expert Systems with Applications, 2012. Publication	<1%

39	Florian Kellner, Bernhard Lienland, Sebastian Utz. "An a posteriori decision support methodology for solving the multi-criteria supplier selection problem", European Journal of Operational Research, 2018 Publication	<1 %
40	Kiran Mehta, Renuka Sharma, Vishal Vyas. "Efficiency and ranking of sustainability index of India using DEA-TOPSIS", Journal of Indian Business Research, 2019 Publication	<1 %
41	Mavi, Reza Kiani. "Green supplier selection: a fuzzy AHP and fuzzy ARAS approach", International Journal of Services and Operations Management, 2015. Publication	<1 %

Exclude quotes	Off	Exclude matches	< 1 words
Exclude bibliography	Off		