Green supplier selection and order allocation using AHPSAW and goal programming

by Universitas Internasional Semen Indonesia

RESEARCH ARTICLE | JULY 25 2022

Green supplier selection and order allocation using AHP-SAW and goal programming

Teguh Baroto ✉; Dana Marsetiya Utama; M. Faisal Ibrahim

AIP Conference Proceedings 2453, 020044 (2022)
https://doi.org/10.1063/5.0094252

Green Supplier Selection and Order Allocation Using AHP-SAW and Goal Programming

Teguh Baroto[1a)], Dana Marsetiya Utama[1,b)], M. Faisal Ibrahim[2)]

[1]Department of Industrial Engineering, Universitas Muhammadiyah Malang, Malang, Indonesia
[2]Department of Logistics Engineering, Semen Indonesia International University, Indonesia

Corresponding author: [a)]teguh@umm.ac.id
[a)]dana@umm.ac.id

Abstract. In the supply chain, environmental aspects become a concern for stakeholders. One of the strategic decisions in the supply chain field is Green Supplier Selection and Order Allocation (GSSOA). This study proposes the Analytical Hierarchy Process (AHP) and simple additive weight (SAW) and Goal Programming procedures in addressing the GSSOA problem. The five criteria and 13 sub-criteria are utilized in applied to plastic manufacturing companies. Based on AHP, the results indicate that quality criteria present a higher level of importance than cost, delivery, service, and environment. Furthermore, the suitability of the material with specifications (QU1) serves as the sub-criteria with the highest weight. The result of the preference assessment with SAW further indicates that supplier 2 presents the highest preference. The application of goal programming is advantageous to determine the optimal order allocation. The results depict that suppliers 2 and 3 are eligible to supply 150 each to fulfill demand.

INTRODUCTION

Supply chain management (SCM) is designed with integrated planning and control decisions to optimize customer satisfaction and business profitability [1]. When environmental awareness grows, it increasingly generates stakeholder concern to solve environmental problems [2]. Green supply chain management (GSCM) thus provides the right concept to balance economic and environmental factors in the supply chain. In SCM, procurement is considered an important activity to improve company performance. Suppliers contribute to the smooth production process [3, 4] [5], capable of improving the company performance [6]. Therefore, the proper suppliers are importantly selected by the company to maintain business competition [7]. Supplier selection and order allocation processes are thus required by considering qualitative and quantitative variables [8]. In the traditional concept, environmental aspects have been previously excluded from supplier selection and order allocation [9] [10]. Therefore, environmental aspects are pivotal to be considered in supplier selection and order allocation. This problem is popularly referred to as green supplier selection and order allocation (GSSOA).

Researchers have published several studies on GSSOA. Examples include Bakeshlou, et al. [11] proposing the Fuzzy Analytic Network Process (ANP), fuzzy Decision Making Trial and Evaluation Laboratory (Dematel), and multi-objective linear programming (MOLP) methods. Similarly, Hamdan and Cheaitou [12]offered fuzzy Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (Topsis), and MOLP. Several other procedures were also proposed, including fuzzy ANP, fuzzy DEMATEL, fuzzy Topsis, and weighted goal programming[13], and multi-objective mixed-integer linear programming and DEA [14]. The Double Hierarchy Hesitant Linguistic Term sets and MOLP procedure was particularly proposed by You, et al. [15]. The Fuzzy Goal Programming With Multiple Importance Function method was developed byWong [16]. Recently, several advanced procedures have been proposed, such as a distributional robust goal programming model and tractable approximation.[17], combined with the Best-Worst Method and fuzzy Topsis [18].

In previous studies, the cost of fuel in the delivery of raw materials is rarely considered. Therefore, this study develops an order allocation model by considering the environmental aspects of fuel consumption costs. Furthermore, a goal programming mathematical model is proposed to model the cost of fuel consumption. Therefore, this study proposes a GSSOA procedure by integrating the AHP- simple additive weight (SAW) procedure and Goal programming. This selected model serves as the novelty of this study because this procedure has never been applied in GSSOA. On the other hand, AHP-SAW has been successfully applied to prioritize renewable energy resources[19] and supplier selection [20]. Furthermore, goal programming procedures have been applied to

1st International Conference on Technology, Informatics, and Engineering
AIP Conf. Proc. 2453, 020044-1–020044-6; https://doi.org/10.1063/5.0094252
Published by AIP Publishing. 978-0-7354-4356-3/$30.00

various problems such as lot sizing[21], and truck allocation [22]. Hence, such aforementioned notion encourages this study to propose AHP-SAW and goal programming in addressing GSSOA problems. In addition, a case study is presented on a manufacturing company in Indonesia.

METHODS

Proposed Method in GSSOA

This section describes a proposed procedure in addressing the GSSOA problem. Figure 1 indicates the five main stages in solving this problem.

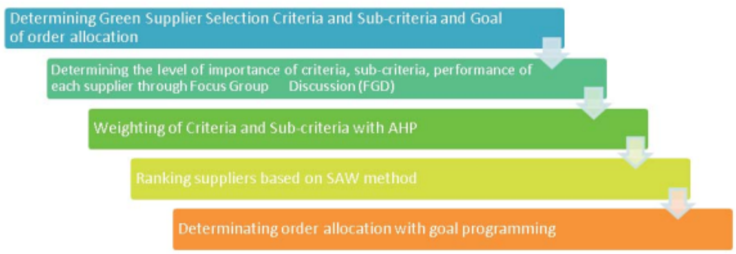

FIGURE 1. The proposed framework for evaluating teacher teaching performance

The first framework is conducted to determine the criteria, sub-criteria, and goals for the GSSOA problem. Focus group discussion (FGD) is proposed to identify criteria, sub-criteria, and goals on this issue. The second stage in the framework is conducted to determine the importance of criteria and sub-criteria through FGD. The AHP method is proposed for weighting the GSSOA criteria and sub-criteria. This method was proposed by Saaty [23], weighting the pairwise comparison scales of 1 (equal importance) to 9 (absolutely more critical). Furthermore, the assessment of each supplier based on each sub-criterion was also conducted through FGDs. For example, some criteria present a rating scale based on a Likert scale of 1 (not good) to 5 (very good). In addition, interval and ratio rating scales are applied to the assessment of each supplier.

The third stage is conducted by weighing the criteria and sub-criteria of the GSSOA problem utilizing AHP. The results of the pairwise comparison of each criterion and sub-criteria are constructed into a matrix as in Equation 1, indicating a pairwise comparison of the criteria. Determination of the importance of pairwise comparisons on the criteria illustrated in Equation 2. Matrix normalization is applied by dividing the value in each column by the number in each column. The principle of the AHP eigenvector is illustrated in Equation 3. In the AHP method, each pairwise comparison matrix is calculated by the consistency ratio (CR) (Equation 5), based on the ratio of the consistency index (CI) value (Equation 4) to the random index (RI) proposed by Saaty [23]. Calculation of global weight sub-criteria is based on the multiplication between criteria and sub-criteria.

The fourth stage is conducted by ranking the supplier priorities based on the SAW procedure. The results of the supplier assessment are presented in a matrix such as in Equation 6. Furthermore, this matrix is normalized based on Equation 7. The results of the normalization matrix () are illustrated in Equation 8. Meanwhile, the preference value for each supplier can be calculated by Equation 9. Finally, the supplier priority in the GSSOA problem is selected based on the biggest.RVi value. The followings are Equation 1to Equation 9.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1k} \\ a_{21} & \cdots & a_{2k} \\ a_{k1} & \cdots & a_{kk} \end{bmatrix} \tag{1}$$

$$a_{pq}0, a_{pp} = 1 \tag{2}$$

$$A.w = \lambda_{max}.w \tag{3}$$

$$CI = \frac{\lambda_{max} - k}{k - 1} \tag{4}$$

$$CR = \frac{CI}{RI} \tag{5}$$

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1k} \\ x_{21} & \cdots & x_{2k} \\ x_{i1} & \cdots & x_{ik} \end{bmatrix} \tag{6}$$

$$r_{ik} = \begin{cases} r_{ik} = \dfrac{x_{ik}}{\text{Max } x_{ik}} \text{ If k is benefit attribute} \\ r_{ik} = \dfrac{\text{Min } x_{ik}}{x_{ik}} \text{ If k is cost attribute} \end{cases} \quad (7)$$

$$R = \begin{bmatrix} r_{11} & \dots & r_{1k} \\ r_{21} & \dots & r_{2k} \\ r_{i1} & \dots & r_{ik} \end{bmatrix} \quad (8)$$

$$V_i = \sum_{k=1}^{q} w_j \, r_{ik} \quad (9)$$

The fifth stage is conducted by determining the order allocation using the goal programming method. The output generated in SAW is utilized as one of the goals to maximize the total weight of the purchase. This study sets five goals in order allocation optimization. The goal programming notations are as follows:

- i : supplier index, i = 1, 2, 3, …, n
- j : index goal, j = 1, 2, 3, …, m
- X_i : supplier order quantity-i
- Y_i : binary integer 0 AND 1
- G_j : The target to be achieved by the goal j
- Vi : supplier-i preference based on AHP-SAW
- Pi : product price supplier-i
- Oi : supplier ordering cost-i
- qi : supplier defect rate-i
- Dis_i : distance supplier-i
- Kpl : fuel consumption liter/kilometer
- Ki : supply capacity of supplier-i
- cf : fuel price
- d_j^+ : positive deviation for goal-j
- d_j^- : negative deviation for goal-j

The mathematical formula of the goal programming model of the GSSOA problem is presented as follows:

$$\min Z = \sum_{j=1}^{m} d_j^+ + d_j^- \quad (10)$$

$$\textstyle\sum_{i=1}^{n} Vi.Xi.Yi + d_1^- - d_1^+ = G1 \quad (11)$$

$$\textstyle\sum_{i=1}^{n} qi.Xi.Yi + d_2^+ - d_2^- = G2 \quad (12)$$

$$\textstyle\sum_{i=1}^{n} Pi.Xi.Yi + d_3^- - d_3^+ = G3 \quad (13)$$

$$\textstyle\sum_{i=1}^{n} Oi.Yi + d_4^- - d_4^+ = G4 \quad (14)$$

$$\textstyle\sum_{i=1}^{n} \left(\frac{Dis_i}{Kpl} * C_f\right) Yi + d_5^- - d_5^+ = G5 \quad (15)$$

$$\textstyle\sum_{i=1}^{n} Xi = D \quad (16)$$

$$Xi \leq Ki.Yi \quad (17)$$

$$d_j^+, d_j^- \geq 0, j = 1,2, \dots, m \quad (18)$$

$$Xi \geq 0, i = 1,2, \dots, n \quad (19)$$

$$Yi \geq 0 \text{ or } 1, i = 1,2, \dots, n \quad (20)$$

Equation 10 contains the objective function of the mathematical model to minimize the deviation from the goal. Equation 11 indicates that goal 1 is to maximize total supplier purchasing preferences. Equation 12 indicates that the goal 2 is aimed at minimizing defective goods from suppliers. Equation 13 indicates that goal 3 is to minimize the purchase price from suppliers. Furthermore, Equation 14 indicates that goal 4 is to minimize the cost of ordering from suppliers. Formula goal 5 is to minimize transportation costs as indicated by Equation 15. Equation 16 indicates the demand constraint. Equation 17 presents a formula that shows the limit of supplier capacity. Equation 18 indicates that the positive and negative deviation of the goal cannot be less than 0. Equation 19 indicates that the limitation that the order quantity of supplier-i cannot be negative. Meanwhile, Equation 20 indicates that it is a binary number that represents whether an order was made from supplier i.(X_i) Y_i

Case study

In this study, a case study was conducted on the Plastic Manufacturing Industry in Indonesia. The purchasing manager and purchasing staff were selected as the FGD panel team. To address the GSSOA problem, the five criteria and 13 sub-criteria are utilized to solve the problem. Table 1 indicates the criteria and sub-criteria used in the GSSOA problem. FGD was carried out in a pairwise comparison assessment of criteria and sub-criteria. The results of the assessment of 4 suppliers in each sub-criteria are illustrated in Table 2. In this assessment, the sub-criteria QU3, CO1, and CO2 employ the interval and ratio assessment scales. In addition, the assessment was conducted using a Likert scale. The goal programming data for the GSSOA problem is presented in Table 3. The KPL value is 8 kilometers/liter, and the fuel price (Cf) is IDR 7600, and the demand for raw materials is 300.

TABLE 1. Criteria and sub-criteria for supplier selection

Criteria	Sub Criteria	Code	Type	Unit of Measurement
Quality (QU)	- Materials according to specifications	QU1	Benefits	Likert
	- Consistent product quality	QU2	Benefits	Likert
	- Disability rate	QU3	Cost	% Defects
Cost (CO)	- Product Price	CO1	Cost	Price (IDR)
	- Order Fee	CO2	Cost	Cost (IDR)
Delivery (DE)	- Order quantity accuracy	DE1	Benefits	Likert
	- On-time Delivery	DE2	Benefits	Likert
	- Fulfilment capacity	DE3	Benefits	Likert
Services (SE)	- Replacement of damaged goods	SE1	Benefits	Likert
	- Flexible	SE2	Benefits	Likert
Environmental Issues (EN)	- Eco-friendly material	EN1	Benefits	Likert
	- *Environment-related certificates* (ERC)	EN2	Benefits	Likert
	- Fuel consumption in product delivery	EN3	Benefits	Likert

TABLE 2. The results of the supplier assessment for each sub-criteria for each supplier

supplier i	QU1	QU2	QU3	CO1	CO2	DE1	DE2	DE3	SE1	SE2	EN1	EN2	EN3
Supplier 1	3	2	0.025	9500	7500	2	3	3	2	3	2	2	4
Suppliers 2	5	5	0.02	9400	7000	2	4	5	2	2	4	2	3
Suppliers 3	2	4	0.015	9500	7500	2	4	2	5	3	5	2	3
Suppliers 4	2	5	0.015	9450	7400	2	5	3	2	2	3	4	4

TABLE 3. Goal programming data for the GSSOA problem

supplier i	Pi	Oi	*qi*	Distance	Capacity
Supplier 1	9500	7500	0.025	15	100
Suppliers 2	9400	7000	0.02	20	150
Suppliers 3	9500	7500	0.015	15	150
Suppliers 4	9450	7400	0.015	17	100
Goal	2830000	14500	4.75	33250	

RESULTS AND DISCUSSION

The results of the weighting of the five criteria and 13 sub-criteria of GSSOA are presented in Table 4, indicating that the suitability of the material with the specifications (QU1) produces the highest weight followed by Product Price (CO1), and the level of the defect (QU3). The results of this study are by the findings of research conducted by Li, et al. [6]. In the area of GSSOA research, environmental criteria have not become a company priority, confirming the research findings of Erfaisalsyah, et al. [24], revealing that environmental criteria have low importance.

In addressing the GSSOA problem, AHP weight is utilized as an assessment of supplier priority preferences. The results of the preference calculation with SAW are presented in Figure 2, indicating that the priority order of suppliers is supplier 2, supplier 1, supplier 3, and the lowest priority is supplier 4. However, the preference values of supplier 1, supplier 3, and supplier 4 are not significantly different. Furthermore, these results are employed as order allocation optimization. Based on linear programming optimization, goal 1 of the total supplier purchasing preference is 270.95.

TABLE 4. Results of weighting criteria and sub-criteria of green supplier selection

No	Criteria	Weight	Sub-Criteria Code	Weight	Global Weight
1	Quality (QU)	0.360	QU1	0.5710	0.2056
			QU2	0.1430	0.0515
			QU3	0.2860	0.1030
2	Cost (CO)	0.254	CO1	0.6670	0.1694
			CO2	0.3330	0.0846
3	Delivery (DE)	0.182	DE1	0.4290	0.0781
			DE2	0.4290	0.0781
			DE3	0.1430	0.0260
4	Services (SE)	0.111	SE1	0.3330	0.0370
			SE2	0.6670	0.0740
5	Environmental Issues (EN)	0.094	EN1	0.2000	0.0188
			EN2	0.2000	0.0188
			EN3	0.6000	0.0564

Based on optimization with goal programming, the optimal order allocation is as follows: the order quantity at suppliers 2 and 3 is 150. In optimal results, Goal 1 and Goal 3 are not achieved. Goal 1 has a deviation from the target of 5.9. In goal 3, the optimal value is generated at 5000 deviations.

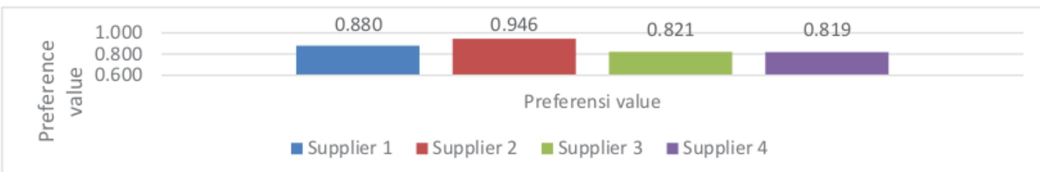

FIGURE 2. The results of the calculation of preferences with the SAW method

CONCLUSION

The research proposes AHP-SAW along with the programming goals in addressing the GSSOA problems. Based on AHP, the suitability of material with specifications (QU1) presents the greatest weight compared to other sub-criteria. Based on SAW, supplier 2 presents a better level of preference among other suppliers. The programming goal results show that order allocation meeting demand is 150 for suppliers 2 and 3. However, this study has limitations that do not consider the interrelationships between criteria and sub-criteria. Thus, further research is encouraged to consider the relationship between criteria and sub-criteria.

REFERENCES

1. P. Ghadimi, F. G. Toosi, and C. Heavey, "A multi-agent systems approach for sustainable supplier selection and order allocation in a partnership supply chain," European Journal of Operational Research, **269** (1), 286-301 (2018).
2. D. M. Utama, B. Maharani, and I. Amallynda, "Integration Dematel and ANP for The Supplier Selection in The Textile Industry: A Case Study," Jurnal Ilmiah Teknik Industri, **20** (1), 119-130 (2021).
3. D. M. Utama, "AHP and TOPSIS Integration for Green Supplier Selection: A Case Study in Indonesia," Journal of Physics: Conference Series, **1845** (1), 012015 (2021).

4. D. M. Utama, T. Baroto, M. F. Ibrahim, and D. S. Widodo, "Evaluation of Supplier Performance in Plastic Manufacturing Industry: A Case Study," Journal of Physics: Conference Series, **1845** (1), 012016 (2021).
5. M. F. Ibrahim, M. M. Putri, and D. M. Utama, "A literature review on reducing carbon emission from supply chain system: drivers, barriers, performance indicators, and practices," IOP Conference Series: Materials Science and Engineering, **722**, 012034 (2020).
6. C. C. Li, Y. P. Fun, and J. S. Hung, "A new measure for supplier performance evaluation," IIE Transactions, **29** (9), 753-758 (1997).
7. D. M. Utama, M. S. Asrofi, and I. Amallynda, "Integration of AHP-MOORA Algorithm in Green Supplier Selection in the Indonesian Textile Industry," Journal of Physics: Conference Series, **1933** (1), 012058 (2021).
8. C. Guo and X. Li, "A multi-echelon inventory system with supplier selection and order allocation under stochastic demand," International Journal of Production Economics, **151**, 37-47 (2014).
9. H.-W. Lo, J. J. Liou, H.-S. Wang, and Y.-S. Tsai, "An integrated model for solving problems in green supplier selection and order allocation," Journal of cleaner production, **190**, 339-352 (2018).
10. D. M. Utama, "Penyelesaian Green Supplier Selection Menggunakan Integrasi AHP dan VIKOR," Prosiding SENTRA (Seminar Teknologi dan Rekayasa), (6), 31-37 (2021).
11. E. A. Bakeshlou, A. A. Khamseh, M. A. G. Asl, J. Sadeghi, and M. Abbaszadeh, "Evaluating a green supplier selection problem using a hybrid MODM algorithm," Journal of Intelligent Manufacturing, **28** (4), 913-927 (2017).
12. S. Hamdan and A. Cheaitou, "Supplier selection and order allocation with green criteria: An MCDM and multi-objective optimization approach," Computers & Operations Research, **81**, 282-304 (2017).
13. E. B. Tirkolaee, A. Mardani, Z. Dashtian, M. Soltani, and G.-W. Weber, "A novel hybrid method using fuzzy decision making and multi-objective programming for sustainable-reliable supplier selection in two-echelon supply chain design," Journal of Cleaner Production, 119517 (2019).
14. H. Moheb-Alizadeh and R. Handfield, "Sustainable supplier selection and order allocation: A novel multi-objective programming model with a hybrid solution approach," Computers & Industrial Engineering, **129**, 192-209 (2019).
15. S.-Y. You, L.-J. Zhang, X.-G. Xu, and H.-C. Liu, "A New Integrated Multi-Criteria Decision Making and Multi-Objective Programming Model for Sustainable Supplier Selection and Order Allocation," Symmetry, **12** (2), 302 (2020).
16. J.-T. Wong, "Dynamic procurement risk management with supplier portfolio selection and order allocation under green market segmentation," Journal of Cleaner Production, **253**, 119835 (2020).
17. R. Jia, Y. Liu, and X. Bai, "Sustainable supplier selection and order allocation: Distributionally robust goal programming model and tractable approximation," Computers & Industrial Engineering, 106267 (2020).
18. M. O. M. Javad, M. Darvishi, and A. O. M. Javad, "Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: a case study of Khouzestan steel company," Sustainable Futures, **2**, 100012 (2020).
19. D. Sedghiyan, A. Ashouri, N. Maftouni, Q. Xiong, E. Rezaee, and S. Sadeghi, "Prioritization of renewable energy resources in five climate zones in Iran using AHP, hybrid AHP-TOPSIS and AHP-SAW methods," Sustainable Energy Technologies and Assessments, **44**, 101045 (2021).
20. T. Baroto and D. M. Utama, "Integrasi AHP dan SAW untuk Penyelesaian Green Supplier Selection," Prosiding SENTRA (Seminar Teknologi dan Rekayasa), (6), 38-44 (2021).
21. W. A. Oliveira, D. J. Fiorotto, X. Song, and D. F. Jones, "An extended goal programming model for the multiobjective integrated lot-sizing and cutting stock problem," European Journal of Operational Research, (2021).
22. M. Mohtasham, H. Mirzaei-Nasirabad, and B. Alizadeh, "Optimization of truck-shovel allocation in open-pit mines under uncertainty: a chance-constrained goal programming approach," Mining Technology, **130** (2), 81-100 (2021).
23. T. L. Saaty, "How to make a decision: the analytic hierarchy process," European journal of operational research, **48** (1), 9-26 (1990).
24. M. Erfaisalsyah, A. Mansur, and A. Khasanah, "Yarn supplier selection using analytical hierarchy process (AHP) and standardized unitless rating (SUR) method on textile industry," AIP Conference Proceedings, **1902** (1), 020011 (2017).

Green supplier selection and order allocation using AHPSAW and goal programming

ORIGINALITY REPORT

7%	12%	3%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	josi.ft.unand.ac.id Internet Source	4%
2	Submitted to School of Business and Management ITB Student Paper	3%

Exclude quotes On
Exclude bibliography On
Exclude matches < 3%