A Robust Hybrid Multi-criteria Decision-Making Approach for Selection of Third-Party Reverse Logistics Service Provider

Arvind Jayant, Shweta Singh, and Tanmay Walke

Abstract Environmental awareness has universally driven the move for sustainable supply chain management. Accordingly, manufacturing companies or organizations try to seek sustainable business strategies to respond to market pressure toward corporate social responsibility (CSR). Sustainable reverse logistics service provider selection is one of the practical strategies for competitive organizations. With the large-scale development of the automotive products industry, sustainable reverse logistics service provider evaluation method is the key for decision authority when dealing with big data information and possible risks of unstructured data. For instance, the choice of decision authority possibly may responsible for a misleading decision, thus leading to undesirable waste of less available resources and time. Therefore, the objective of present work is to apply the integrated multi-criteria decision methods using the "MOORA and WASPAS" approaches in the evaluation of third-party logistics service providers (3PRLSPs). It also incorporates the significance weight provided by SWARA technique and helps decision-makers for efficient decision-making. The proposed model is to evaluate, and criteria weight is determined using the step-wise weight assessment ratio (SWARA) approach and then ranking of the alternatives was decided by MOORA and WASPAS. The automotive parts manufacturing company may be benefited by their commitment toward environmental safety, economic, and corporate social responsibility (CSR) leading to improved brand value and sustainable business development.

Keywords WASPAS · Sustainability · MOORA · MCDM · 3PRLSPs

1 Introduction

Organizations are working towards sustainable development by incorporating sustainability aspects in their business operations. "Sustainability had remained as

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part of many cultures but formal introduction of sustainability as a concern for businesses can be traced to the Brundtland report published in a book entitled 'Our Common Future'. According to World Commission on Environment and Development (1987) sustainability is more accepted which states that: "Sustainable development is the development that gains the need of present generation without causing any effect to the future." Over the years, "sustainability supported by Agenda 21 adopted at United Conference on Environment and Development at Rio de Janeiro, 1992" has emerged as a motivator for global operations to improve their mutual understanding about sustainable development approach and paradigm [1, 2] "propose several reasons as to why growing interest has raised up in reverse logistics worldwide: It is an effectual means to deal with the large load of returned material, particularly for the industries that experience high return rates, at times over 60% of sales."

Reuse or secondary and international level business are increasingly fast growing and hence provide companies with a chance to promote their business sales by secondary or discarded parts and products. There is major difference in management of forward logistics and reverse logistics operation as shown in Table 1. Latest rules and regulations gradually evolved in developed nations in terms of EOL take-back guidelines in the past decade and thus requires OEM to fully manage the complete life cycle of their parts and products.

According to Jayant et. al. [3], "reverse logistics emphasized green logistics in traditionally, that means added environmentally into logistics strategies, including product return, recycling, waste disposal, refurbishing, repair, and remanufacturing." Many industries have recognized the financial impact on RL operations and effective RL could improve industry performance outcomes and secondary level business competitiveness.

The remaining portion of the research work is organized as follows: Sect. 2 explains review of the literature. Section 3 defines the case study problem to be evaluated. Section 4 discusses the proposed research framework including the procedure for implementation of SWARA, MOORA, and WASPAS methods to solve the proposed problem. Section 5 presents the discussion with proposed solutions. Finally,

Table 1 Difference between forward and reverse logistic

Forward logistics	Reverse logistics
"Forecasting relatively straightforward" "One-to-many transportation" "Product quality uniform" "Product packaging unbroken" "Destination/routing clear" "Consistent channel" "Prominence of speed recognized" "Inventory management reliable" "Product life cycle manageable"	"Forecasting more difficult" "Many-to-one transportation" "Product quality not uniform" "Product packaging often broken" "Purpose/routine unclear" "Exception driven" "Temperament not clear" "Pricing dependent on many factors" "Speed often not considered a priority"

Fig. 1 Reverse logistics

Sect. 6 presents the conclusion and future research directions which concludes the case study (Fig. 1).

2 Literature Review

Important criteria for 3PRLSPs are identified through extensive literature review. There are three main criteria of sustainability which further divided into 17 sub-criteria. Further, the 17 very important sustainable supply chain selection and evaluation criteria identified in the case study and criteria's were validated with the help of subject experts' inputs and categorized into three dimensions of sustainability (Social, economic, and environment). The identified criteria are shown with the help of flow diagram below in Table 2.

3 Problem Description

3.1 Company Profile

The case company XYZ Limited started in July 1983. The company has plant situated in Haryana (India). XYZ is a private limited company, manufactured various parts of automotive industry. The strength of the company is its technology, people at work, widest network, accolades, etc. (Tables 3, 4 and 5).

Table 2 Selection and evaluation criteria for sustainable 3PLRSP

Main criteria	Code	Sustainable supplier selection sub-criteria	References
Economic factors	E1	Ordering and logistic cost	Marcin Stępień et al. (2016)
	E2	Custom and insurance cost	Syed A. M. Tofail et al. (2017)
	E3	Quality management	CostacheRusu (2016)
	E4	On time delivery rate	Ricarda Schäfer et al. (2016)
	E5	Transportation	Christopher Hendrickson (2002)
	E6	Delivery and service	Jie Yu et al. (2014)
Social factors	S1	Occupational health and safety program	Kwesi Amponsah-Tawiah and Justice Mensah (2016)
	S2	Operation	Christoph Teller et al. (2018)
	S3	Wages	Yanting Chen, and Qijun Liu (2018)
	S4	Prevention and risk control program	A. Romero Barriuso et al. (2018)
	S5	Flexible working facilities	Suzanne R. Dhaini et al. (2018)
Environmental factors	EN1	Air emission	Yee Van Fan et al. (2018)
	EN2	Wastewater	Nikolay Makisha (2016)
	EN3	Use of harmful material	Nikolay Makisha et al. (2018)
	EN4	Use of environment friendly material and technology	Jiao Chen et al. (2018)
	EN5	Recycle	Huaidong Wang et al. (2018)
	EN6	Reuse	S. Arden and X. Ma (2018)

Table 3 Company profile

Year of establishment	1983
Turnover of company	119628 million
Employees strength	200
Production capacity	1.5 million
Type of parts manufactured	Automobiles, hydraulic brakes. Rubber pads, suspension system, automotive components
Type of business	Manufacturer, supplier

Table 4 Name of the company customers

1	KINGAS	6	Hi-Pad Auto parts Co. Ltd.
2	JBM Group	7	GALCO group
3	Ion Exchange Limited	8	Canara Standard Keys
4	IZEST SDN BHD		
5	Hinduja Foundries		

Table 5 List of suppliers

1	Alex machine tools Pvt. Ltd.
2	Dawn motors Pvt. Ltd.
3	Paras Industry
4	Power India Wheels Co.
5	Metaforge Engineering Pvt. Ltd.
6	Kew Industries Limited

3.2 Industrial Survey

Data collected from ABC automobile industry for 3PRLSPs selection considering the criteria are considered and then ranking of different service providers accordingly. Weight age of the criteria selected on a scale of triangular fuzzy (Table 6).

10 Alternative and 17 criteria are under consideration. These seventeen criteria are E1 Ordering and Logistics cost; E2 Custom and Insurance Cost; E3 Quality management; E4 On time delivery rate; E5 Transportation; E6 Delivery and service; S1 Occupational health and safety program; S2 Operations; S3 Wages; S4 Prevention & risk control program; S5 Flexible working facility; EN1Air emission; EN2 Wastewater; EN3 Use of harmful material; EN4 Use of environment friendly technology and material; EN5 Recycle; EN6 Reuse.

Weight age of each criterion on every alternative is resolute by using MCDM techniques and finally the result gives us the ranking of alternatives. Ranking could be concluded with the help of fuzzy methods so that the problem becomes more structured.

4 Research Framework

See Figs. 2 and 3.

Table 6 The fuzzy scale

Linguistic scale	Response scale
“Equally important”	“(1, 1, 1)”
“Moderately less important”	“(2/3, 1, 3/2)”
“Less important”	“(2/5, 1/2, 2/3)”
“Very less important”	“(2/7, 1/3, 2/5)”
“Much less important”	“(2/9, 1/4, 2/7)”

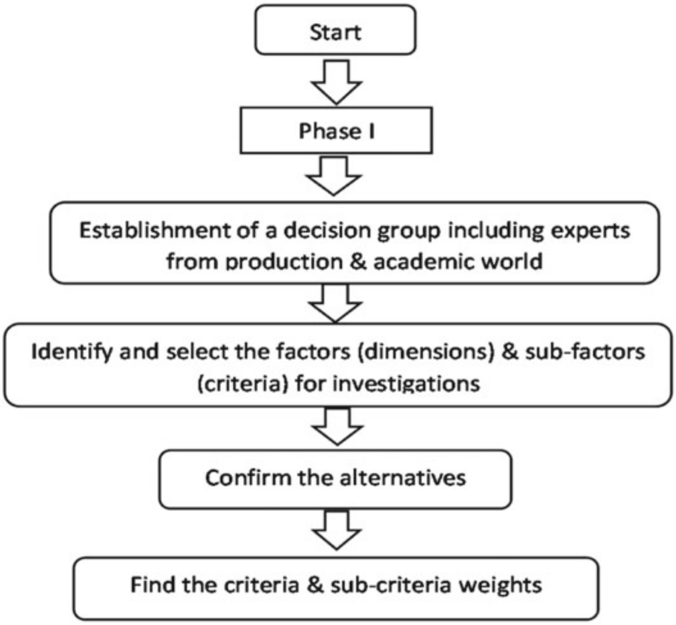

Fig. 2 Phase I of research framework including SWARA method

4.1 Evaluation of Reverse Logistic Provider Selection by Step-Wise Weight Assessment Ratio (SWARA) Method

Since conventional MADM methods cannot meritoriously handle problems with such inexact information, "therefore, fuzzy MADM methods have been developed owed to the inaccuracy in measuring the relative importance of attributes and the performance ratings of alternatives with respect to attributes. Hence, present work aims to extend SWARA to fuzzy SWARA. This assumes that all criteria are independent."

The process of decisive the relative weights of criteria by fuzzy SWARA is as same as the SWARA such as the following steps:

Step 1 Sort the evaluation factors in descending order of expected significance (Tables 7 and 8).

Step 2 According to Table 9, "state the relative importance of the factor j in relation to the previous $(j - 1)$ factor, which has higher importance, and follow to the last factor. After determining all relative importance scores by all experts, to aggregate their judgments, the geometric mean of corresponding scores was obtained. Kersuliene et al. term this ratio as the comparative importance of average value *Sj*."

Step 3 Determine the coefficient *Kj* as follows:

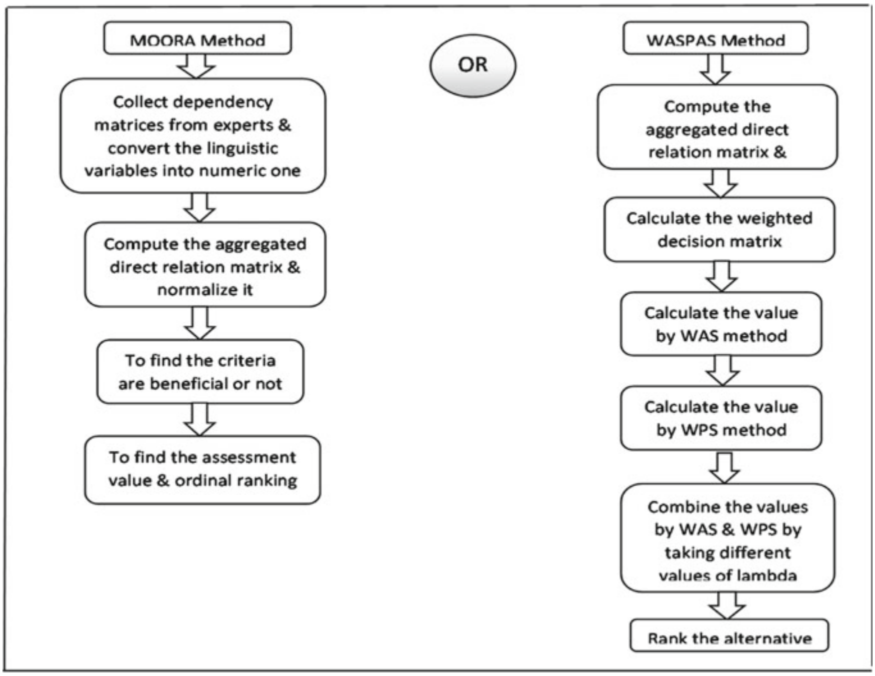

Fig. 3 Phase II of research framework including MOORA and WASPAS

Table 7 The fuzzy scale

Linguistic scale	Response scale
"Equally important"	"(1, 1, 1)"
"Moderately less important"	"(2/3, 1, 3/2)"
"Less important"	"(2/5, 1/2, 2/3)"
"Very less important"	"(2/7, 1/3, 2/5)"
"Much less important"	"(2/9, 1/4, 2/7)"

$$Kj = \begin{cases} 1 & j = 1 \\ Sj + 1 & j > 1 \end{cases}$$

Step 4 Determine the fuzzy weight qj as follows (Table 10):

$$qj = \begin{cases} 1 & j = 1 \\ \frac{Kj-1}{kj} & j > 1 \end{cases}$$

Step 5 The relative weights of the evaluation criteria are determined as follows:

$$wj = \frac{qj}{\sum_{k=1}^{n} qk}$$

Table 8 Comparative importance of average value *Sj*

Criteria	Comparative importance of average value *Sj*		
E1: Ordering and logistic cost	0.286	0.333	0.400
E2: Custom and insurance cost	0.222	0.250	0.286
E3: Quality management	0.667	1.000	1.500
E4: On time delivery rate	0.400	0.500	0.667
E5: Transportation	0.667	1.000	1.500
E6: Delivery and services	1.000	1.000	1.000
S1: Occupational health and safety program	0.667	1.000	1.500
S2: Operations	0.286	0.333	0.400
S3: Wages	0.400	0.500	0.667
S4: Prevention and risk control program	0.222	0.250	0.286
S5: Flexible working facilities	0.400	0.500	0.667
EN 1: Air emission	1.000	1.000	1.000
EN 2: Wastewater	0.667	1.000	1.500
EN 3: Use of harmful material	0.400	0.500	0.667
EN4: Use of env. friendly tech. and material	1.000	1.000	1.000
EN5: Recycle	0.667	1.000	1.500
EN 6: Reuse	0.400	0.500	0.667

"where *wj* denotes the relative weight of criterion *j*" (Table 11).
where "$wj = (w_l, w_m, w_u)$ is the relative fuzzy weight of the *j*th criterion and n shows the number of evaluation criteria".
Basic arithmetic operations on triangular fuzzy numbers "$A1 = (l_1, m_1, u_1)$,"
where "$l_1 \leq m_1 \leq u_1$ and $A2 = (l_2, m_2, u_2)$".
where "$l_2 \leq m_2 \leq u_2$" is done as follows:

- "Fuzzy addition":
  "$A1 \oplus A2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$"
- "Fuzzy subtraction":
  "$A1 \ominus A2 = (l_1 - U_2; m_1 - m_2; U_1 - l_2)$"
- "Fuzzy multiplication":
  "$A1 \otimes A2 = l_1 l_2; m_1 m_2; u_1 u_2$"
- "Fuzzy division":
  "$A1 \oslash A2 = l_1/U_2; m_1/m_2; U_1/l_2$"

Step 6 Using above steps find the fuzzy weight for criteria (Table 12).
Step 7 Final weights for each sub-criteria (Table 13 and Fig. 4).

Table 9 Value of coefficient *Kj*

Criteria	Coefficient $Kj = Sj + 1$		
E1: Ordering and logistic cost	1.000	1.000	1.000
E2: Custom and insurance cost	1.222	1.250	1.286
E3: Quality management	1.667	2.000	2.500
E4: On time delivery rate	1.400	1.500	1.667
E5: Transportation	1.667	2.000	2.500
E6: Delivery and services	2.000	2.000	2.000
S1: Occupational health and safety program	1.667	2.000	2.500
S2: Operations	1.286	1.333	1.400
S3: Wages	1.400	1.500	1.667
S4: Prevention and risk control program	1.222	1.250	1.286
S5: Flexible working facilities	1.400	1.500	1.667
EN 1: Air emission	2.000	2.000	2.000
EN 2: Wastewater	1.667	2.000	2.500
EN 3: Use of harmful material	1.400	1.500	1.667
EN4: Use of env. Friendly tech. and material	2.000	2.000	2.000
EN5: Recycle	1.667	2.000	2.500
EN 6: Reuse	1.400	1.500	1.667

4.2 Evaluation of Reverse Logistic Provider Selection by MOORA Method

Brauers and Zavadskas introduced "fuzzy MOORA in a privatization-themed study in subsistence economy as a MCDM method. There are three different approaches for solving problems with fuzzy MOORA: fuzzy ratio method, reference point approach, and full multiplicative form. In this paper, we use the fuzzy ratio method of Mavi et. al. [4]."

Step 1 Construct the decision matrix using triangular fuzzy numbers

$$\begin{bmatrix} (x^l_{11k,} x^m_{11k}, x^u_{11k}) & \cdots & (x^l_{1nk,} x^m_{1nk}, x^u_{1nk}) \\ \vdots & \ddots & \vdots \\ (x^l_{1mk}, x^m_{1mk}, x^u_{1mk}) & \cdots & (x^l_{mnk}, x^m_{mnk}, x^u_{mnk}) \end{bmatrix}$$

where "*m* is the number of alternatives, *n* is the number of criteria, and *xmnk* presents the judgment of decision-maker *k* ($k = 1; 2; \ldots; K$) about the performance of alternative *i* in criterion *j*. Fuzzy numbers (*xijki*, *xijkm*, *xijku*) are assigned to each alternative based on Table 14."

Step 1–1: Obtain the aggregated decision matrix, $\tilde{X}$;

Table 10 Recalculated fuzzy weight *qj*

Criteria	Coefficient $Kj = Sj + 1$			Recalculated weight qj		
E1: Ordering and logistic cost	1.000	1.000	1.000	1.0000	1.0000	1.0000
E2: Custom and insurance cost	1.222	1.250	1.286	0.7770	0.8000	0.8180
E3: Quality management	1.667	2.000	2.500	0.3110	0.4000	0.4900
E4: On time delivery rate	1.400	1.500	1.667	0.1860	0.2660	0.3500
E5: Transportation	1.667	2.000	2.500	0.0740	0.1330	0.2100
E6: Delivery and services	2.000	2.000	2.000	0.0370	0.0660	0.1050
S1: Occupational health and safety program	1.667	2.000	2.500	0.0140	0.0330	0.0620
S2: Operations	1.286	1.333	1.400	0.0100	0.0250	0.0480
S3: Wages	1.400	1.500	1.667	0.0063	0.0160	0.0340
S4: Prevention and risk control program	1.222	1.250	1.286	0.0049	0.0130	0.0270
S5: Flexible working facilities	1.400	1.500	1.667	0.0029	0.0080	0.0190
EN 1: Air emission	2.000	2.000	2.000	0.0014	0.0040	0.0090
EN 2: Wastewater	1.667	2.000	2.500	0.0006	0.0020	0.0053
EN 3: Use of harmful material	1.400	1.500	1.667	0.0004	0.0014	0.0037
EN4: Use of env. friendly tech. and material	2.000	2.000	2.000	0.0002	0.0007	0.0018
EN5: Recycle	1.667	2.000	2.500	0.0001	0.0003	0.0011
EN 6: Reuse	1.400	1.500	1.667	0.0000	0.0002	0.0007
Total				2.42572	2.7686	3.1846

$$“\begin{bmatrix} (x^l_{11k,} x^m_{11k}, x^u_{11k}) & \cdots & (x^l_{1nk,} x^m_{1nk}, x^u_{1nk}) \\ \vdots & \ddots & \vdots \\ (x^l_{1mk}, x^m_{1mk}, x^u_{1mk}) & \cdots & (x^l_{mnk}, x^m_{mnk}, x^u_{mnk}) \end{bmatrix}”$$

where

$$“x^l_{ij} = \frac{\sum_{k-1}^{k} x^l_{ijk}}{k}, x^m_{ij} = \frac{\sum_{k-1}^{k} x^m_{ijk}}{k}, x^u_{ij} = \frac{\sum_{k-1}^{k} x^u_{ijk}}{k}”$$

Step 2 “Normalize the aggregated initial decision matrix to form a more comparable structure”.

As $\widetilde{r_{ij}} = (r^l_{ij}, r^m_{ij}, r^u_{ij})$

Table 11 Relative weights of evaluation criteria

Criteria	Fuzzy weight *qj*			Weight *wj*		
E1: Ordering and logistic cost	1.0000	1.0000	1.0000	0.314011	0.361193	0.41225
E2: Custom and insurance cost	0.7770	0.8000	0.8180	0.243987	0.288955	0.33722
E3: Quality management	0.3110	0.4000	0.4900	0.097657	0.144477	0.20200
E4: On time delivery rate	0.1860	0.2660	0.3500	0.058406	0.096077	0.14429
E5: Transportation	0.0740	0.1330	0.2100	0.023237	0.048039	0.08657
E6: Delivery and services	0.0370	0.0660	0.1050	0.011618	0.023839	0.04329
S1: Occupational health and safety program	0.0140	0.0330	0.0620	0.004396	0.011919	0.02556
S2: Operations	0.0100	0.0250	0.0480	0.003140	0.009030	0.01979
S3: Wages	0.0063	0.0160	0.0340	0.001978	0.005779	0.01402
S4: Prevention and risk control program	0.0049	0.0130	0.0270	0.001539	0.004696	0.01113
S5: Flexible working facilities	0.0029	0.0080	0.0190	0.000911	0.002890	0.00783
EN 1: Air emission	0.0014	0.0040	0.0090	0.000440	0.001445	0.00371
EN 2: Wastewater	0.0006	0.0020	0.0053	0.000185	0.000722	0.00218
EN 3: Use of harmful material	0.0004	0.0014	0.0037	0.000110	0.000506	0.00153
EN4: Use of env friendly tech. and material	0.0002	0.0007	0.0018	0.000053	0.000253	0.00074
EN5: Recycle	0.0001	0.0003	0.0011	0.000022	0.000108	0.00045
EN 6: Reuse	0.0000	0.0002	0.0007	0.000013	0.000072	0.00029

"$r_{ij}^{l} = x_{ij}^{l} / \sqrt{\sum_{i=1}^{m}\left[\left(x_{ij}^{l}\right)^{2} + (x_{ij}^{m})^{2} + (x_{ij}^{u})^{2}\right]}$"

"$r_{ij}^{m} = x_{ij}^{m} / \sqrt{\sum_{i=1}^{m}\left[\left(x_{ij}^{l}\right)^{2} + (x_{ij}^{m})^{2} + (x_{ij}^{u})^{2}\right]}$"

"$r_{ij}^{u} = x_{ij}^{u} / \sqrt{\sum_{i=1}^{m}\left[\left(x_{ij}^{l}\right)^{2} + (x_{ij}^{m})^{2} + (x_{ij}^{u})^{2}\right]}$"

Step 3 "Obtain the weighted normalized fuzzy decision matrix by multiplying normalized fuzzy decision matrix and diagonal matrix of weights obtained from fuzzy SWARA."

As $\tilde{v}_{ij} = (v_{ij}^{l}, v_{ij}^{m}, v_{ij}^{u})$ where $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_{j}$

Step 4 Compute the normalized performance values by subtracting the cost criteria from the total of benefit criteria

Table 12 Fuzzy weight for main criteria

Criteria	*Sj*			$Kj = 1 + Sj$			Recalculated weight *qj*			Weight		
C1: Economic				1.00	1.000	1.000	1.000	1.000	1.000	0.4352	0.4545	0.4838
C2: Environment	0.400	0.500	0.667	1.400	1.500	1.667	0.600	0.667	0.714	0.2611	0.3032	0.3454
C3: Social	0.222	0.250	0.286	1.222	1.250	1.286	0.467	0.533	0.584	0.2032	0.2423	0.2825
Total							2.067	2.200	2.298			

Table 13 Final weight of sub-criteria

Criteria	Weight *wj*			Final weights		
E1: Ordering and logistic cost	0.314011	0.361193	0.41225	0.1366454	0.164179	0.199443
E2: Custom and insurance cost	0.243987	0.288955	0.33722	0.1061735	0.131343	0.163144
E3: Quality management	0.097657	0.144477	0.20200	0.0424967	0.065672	0.097727
E4: On time delivery rate	0.058406	0.096077	0.14429	0.0254160	0.043672	0.069805
E5: Transportation	0.023237	0.048039	0.08657	0.0101118	0.021836	0.041883
E6: Delivery and services	0.011618	0.023839	0.04329	0.0050559	0.010836	0.020942
S1: Occupational health and safety program	0.004396	0.011919	0.02556	0.0008934	0.002888	0.007221
S2: Operations	0.003140	0.009030	0.01979	0.0006381	0.002188	0.005591
S3: Wages	0.001978	0.005779	0.01402	0.0004020	0.001400	0.003960
S4: Prevention and risk control program	0.001539	0.004696	0.01113	0.0003127	0.001138	0.003145
S5: Flexible working facilities	0.0009	0.0028	0.007	0.00018	0.0007	0.00221
EN 1: Air emission	0.000440	0.001445	0.00371	0.0001148	0.000438	0.001282
EN 2: Wastewater	0.000185	0.000722	0.00218	0.0000483	0.000219	0.000755
EN 3: Use of harmful material	0.000110	0.000506	0.00153	0.0000286	0.000153	0.000527
EN4: Use of env. friendly tech. and material	0.000053	0.000253	0.00074	0.0000139	0.000077	0.000256
EN5: Recycle	0.000022	0.000108	0.00045	0.0000057	0.000033	0.000157
EN 6: Reuse	0.000013	0.000072	0.00029	0.0000033	0.000022	0.000100

$$\widetilde{Yi} = \sum_{j=1}^{g} \widetilde{v_{ij}} - \sum_{j=g+1}^{n} \widetilde{v_{ij}}$$

"Here,
$\sum_{j=1}^{g} \widetilde{v_{ij}}$ Benefit criteria for 1, …, g
$\sum_{j=g+1}^{n} \widetilde{v_{ij}}$ Cost criteria for $g + 1, \ldots, n$
g, maximum number of criteria to be done.
$(n - g)$, minimum number of criteria to be done."

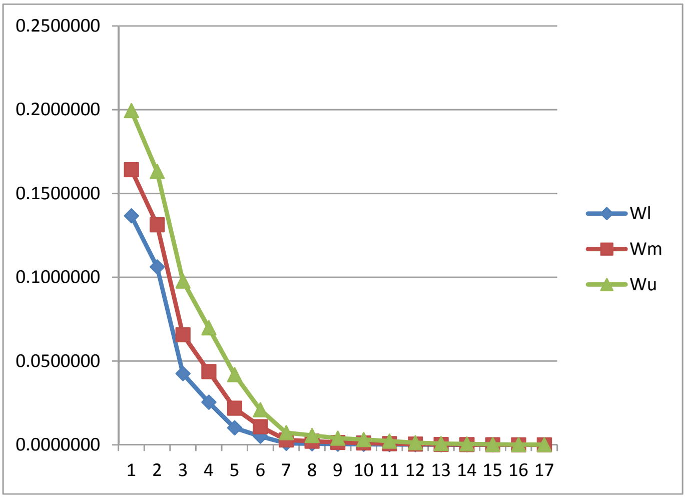

Fig. 4 Results by fuzzy SWARA

Table 14 Transformation for fuzzy membership functions

Linguistic scale	Triangular fuzzy numbers	Attribute grade
"Very low (VL)"	"(0, 0, 0.25)"	"1"
"Low (L)"	"(0, 0.25, 0.5)"	"2"
"Medium (M)"	"(0.25, 0.5, 0.75)"	"3"
"High (H)"	"(0.5, 0.75, 1)"	"4"
"Very high (VH)"	"(0.75, 1.0, 1.0)"	"5"

Ranking shows that alternative I is the best among all alternatives and alternative D is the worst choice (Table 15 and Fig. 5).

4.3 Evaluation of Reverse Logistic Provider Selection by WASPAS Method

This "subsection extends WASPAS to the fuzzy atmosphere. The worth of using a fuzzy approach is to allocate the relative importance of attributes using fuzzy numbers instead of accurate numbers."

The WASPAS method consists of two aggregated parts:

1. Weighted Sum Model (WSM);
2. Weighted Product Model (WPM).

Based on the briefly summarized fuzzy theory above, Fuzzy WASPAS steps can be outlined as follows:

Table 15 Best non-fuzzy performance value and ranking

3PRLP	Y_i			BNP(Yi)	Ranking
	Y_i^l	Y_i^m	Y_i^u		
A	0.0204	−0.0174	−0.0208	−0.0077	6
B	0.0171	−0.0295	−0.0315	−0.0146	2
C	0.0257	−0.0262	−0.0270	−0.0092	5
D	0.0269	−0.0155	−0.0213	−0.0033	10
E	0.0346	−0.0244	−0.0268	−0.0055	8
F	0.0286	−0.0221	−0.0227	−0.0054	9
G	0.0315	−0.0265	−0.0269	−0.0073	7
H	0.0170	−0.0215	−0.0262	−0.0102	4
I	0.0236	−0.0350	−0.0373	−0.0162	1
J	0.0235	−0.0289	−0.0362	−0.0138	3

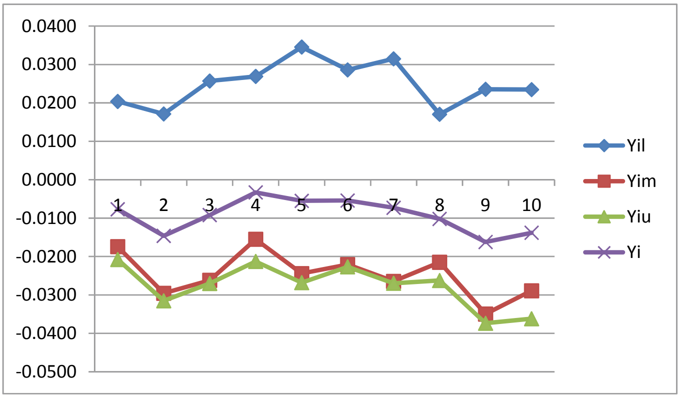

Fig. 5 Results by MOORA method

Step 1 Creating of fuzzy DM matrix (FDMM). The performance values $\tilde{xij}$ and the attributes weights $\tilde{wj}$ are entries of a DMM. Choose the linguistic ratings. "The structure of attributes as well as the values and initial weights of attributes are determined by decision-makers' experts. The distinct optimization problem is characterized by the partialities for m reasonable alternatives (rows) rated on n attributes (columns)":

$$\tilde{X} = \begin{bmatrix} \widetilde{X_{11}} \ldots \widetilde{X_{1j}} \ldots \widetilde{X_{1n}} \\ \widetilde{X_{i1}} \ldots \widetilde{X_{ij}} \ldots \widetilde{X_{in}} \\ \widetilde{X_{m1}} \ldots \widetilde{X_{m1}} \ldots \widetilde{X_{mn}} \end{bmatrix}; \; i = 1, m, \; j = 1, n,$$

"where $\tilde{X}_{ij}$– fuzzy value representing the performance value of the i alternative in terms of the j attribute. A tilde ˜ is placed above a symbol if the symbol represents a fuzzy set. Then the purpose of the priorities of alternatives is conceded out in several steps."

Step 2 "The initial values of all the attributes $\tilde{X}_{ij}$ are normalized—defining values $\bar{X}_{ij}$ of normalized decision-making matrix $\bar{X} = \left[\bar{X}_{ij}\right] m \times n$."

$$\overline{\overline{X_{ij}}} = \begin{cases} \dfrac{\widetilde{X_{ij}}}{\max\limits_{i} \widetilde{X_{ij}}} \text{ if } \max\limits_{i} \widetilde{X_{ij}} \text{ is preferable} \\ \dfrac{\min\limits_{i} \widetilde{X_{ij}}}{\widetilde{X_{ij}}} \text{ if } \min\limits_{i} \widetilde{X_{ij}} \text{ is preferable} \end{cases} \quad i = 1, m, \ j = 1, n.$$

Step 3a Compute the weighted normalized fuzzy DM Xq for WSM.
Step 3b Compute the weighted normalized fuzzy DM Xp for WPM.
Step 4 Compute the value of optimality function:
"According to the WSM for each alternative":
$\tilde{Q}i = \sum_{j=1}^{n} \tilde{x}_{ij}, i = 1, m,$
According to the WPM for each alternative:
$\tilde{P}i = \prod_{j=1}^{n} \tilde{x}_{ij}, i = 1, m.$
The result of fuzzy performance measurement for each alternative is fuzzy numbers $\tilde{Q}i$ and $\tilde{P}i$. The center-of-area is the most practical and simple to apply for defuzzification:
$Qi = \frac{1}{3}(Qi\alpha + Qi\beta + Qi\gamma)$
$Pi = \frac{1}{3}(Pi\alpha + Pi\beta + Pi\gamma)$
Step 5 "The integrated utility function value of the WASPAS-F method for an alternative could be determined as follows":
$Ki = \lambda \sum_{j=1}^{m} Qi + (1 - \lambda) \sum_{j=1}^{m} Pi, \lambda = 0, \ldots, 0.1, 0 \leq Ki \leq 1.$
Step 6 "Rank preference orders. Choose an alternative with maximal *Ki* value".

It shows that the service provider mentioned as A is the best choice and service provider mentioned as D is the worst choice among alternatives as shown in Fig. 6 (Tables 16 and 17).

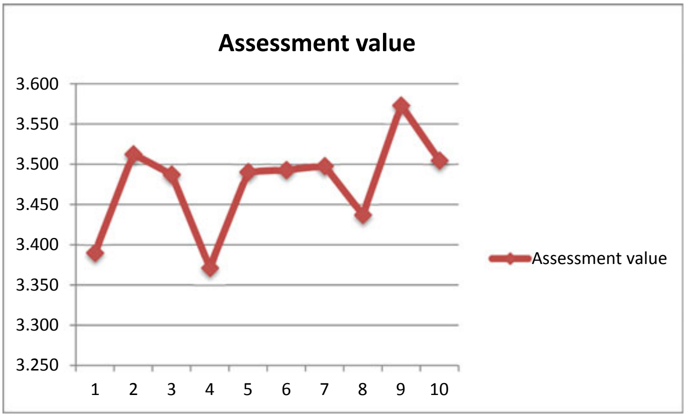

Fig. 6 Results by WASPAS method

5 Discussion and Proposed Solution

Comparative analysis ranking of case alternatives as per implementation of WASPAS and MOORA is given in Table 18. According to MOORA method "alternatives are ranked as I > B > J > H > C > A > G > E > F > D in the decreasing order of preference," and "according to WASPAS method alternatives are ranked as I > B > J > G > F > E > C > H > A > D in the decreasing order of preference." It is clear from the ranking results of the two MCDM approaches MOORA and WASPAS method that 3PRLSPS designated as I is the best choice for the given automobile industry operation under the given conditions while RLSP designated as D is the worst choice.

RLSP I is ideal according to the criteria transportation (E5), wastewater (EN2), use of harmful material (EN3), reuse (EN6) and closer to ideal according to the criteria ordering and logistic cost (E1), quality management (E3), on time delivery rate (E4), use of environment friendly material (EN4) and farthest to the ideal according to the criteria recycle (EN5).

RLSP B is ideal according to the criteria custom and insurance cost (E2), reuse (EN6) and closer to ideal conferring to the criteria transportation (E5), wages (S3), use of harmful material (EN3) and farthest to the ideal according to criteria Ordering and logistic cost (E1), wastewater (EN2), use of environment friendly material (EN4).

As an alternative for a final solution, service provider designated as I could be considered the best compromise from the ranking results of MOORA and WASPAS method.

Finally, study concludes that "the ranking depends on the judgments of relative importance made by the user. The ranking may change if the user assigns different relative importance values to the criteria's. The same is true with all these MCDM approaches (Table 19)."

Table 16 Qi value for WSM

3PRLP (Qi)	E1	E2	E3	E4	E5	E6	S1	S2	S3	S4	S5	EN1	EN2	EN3	EN4	EN5	EN6
A	0.1668	0.1103	0.0463	0.0242	0.0243	0.0105	0.0029	0.0022	0.0017	0.0010	0.0007	0.0004	0.0003	0.0003	0.0001	0.0001	0.0001
B	0.1096	0.0908	0.0579	0.0342	0.0239	0.0115	0.0032	0.0023	0.0013	0.0014	0.0009	0.0007	0.0003	0.0003	0.0002	0.0001	0.0001
C	0.1154	0.1001	0.0629	0.0335	0.0155	0.0083	0.0037	0.0028	0.0016	0.0010	0.0007	0.0004	0.0004	0.0002	0.0001	0.0001	0.0001
D	0.1308	0.1336	0.0537	0.0392	0.0178	0.0123	0.0027	0.0022	0.0014	0.0013	0.0011	0.0005	0.0003	0.0002	0.0002	0.0001	0.0001
E	0.1274	0.0967	0.0612	0.0388	0.0206	0.0105	0.0036	0.0029	0.0011	0.0014	0.0008	0.0004	0.0003	0.0002	0.0002	0.0001	0.0001
F	0.1106	0.1118	0.0662	0.0331	0.0226	0.0110	0.0034	0.0025	0.0014	0.0013	0.0008	0.0005	0.0003	0.0002	0.0001	0.0001	0.0001
G	0.1195	0.0923	0.0703	0.0257	0.0242	0.0087	0.0029	0.0017	0.0017	0.0016	0.0009	0.0005	0.0003	0.0002	0.0001	0.0001	0.0001
H	0.1274	0.1213	0.0496	0.0351	0.0216	0.0109	0.0021	0.0021	0.0020	0.0011	0.0009	0.0005	0.0003	0.0002	0.0001	0.0001	0.0001
I	0.0881	0.0844	0.0678	0.0463	0.0216	0.0107	0.0026	0.0023	0.0015	0.0011	0.0009	0.0006	0.0002	0.0002	0.0002	0.0001	0.0001
J	0.0971	0.1051	0.0653	0.0304	0.0174	0.0089	0.0031	0.0027	0.0017	0.0013	0.0009	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001

Table 17 *Pi* value for WPM

3PRLP (Pi)	E1	E2	E3	E4	E5	E6	S1	S2	S3	S4	S5	EN1	EN2	EN3	EN4	EN5	EN6
A	1.0000	0.9691	0.9685	0.9527	1.0000	0.9972	0.9988	0.9987	0.9996	0.9988	0.9992	0.9994	0.9999	0.9999	1.0000	1.0000	1.0000
B	0.9295	0.9393	0.9855	0.9806	0.9989	0.9985	0.9989	0.9989	0.9989	0.9996	0.9996	1.0000	0.9998	1.0000	1.0000	1.0000	1.0000
C	0.9339	0.9525	0.9944	0.9785	0.9843	0.9929	1.0000	0.9998	0.9995	0.9988	0.9993	0.9993	1.0000	0.9998	1.0000	1.0000	1.0000
D	0.9607	1.0000	0.9822	0.9878	0.9883	1.0000	0.9979	0.9987	0.9987	0.9994	1.0000	0.9996	0.9997	0.9999	1.0000	1.0000	1.0000
E	0.9588	0.9464	0.9946	0.9873	0.9946	0.9966	0.9996	1.0000	0.9980	0.9997	0.9995	0.9993	0.9997	0.9999	1.0000	1.0000	1.0000
F	0.9288	0.9702	0.9969	0.9779	0.9967	0.9977	0.9993	0.9994	0.9989	0.9994	0.9995	0.9996	0.9999	0.9999	1.0000	1.0000	1.0000
G	0.9436	0.9385	1.0027	0.9616	0.9990	0.9938	0.9986	0.9978	0.9995	1.0000	0.9998	0.9996	0.9997	0.9999	1.0000	1.0000	1.0000
H	0.9588	0.9838	0.9719	0.9823	0.9951	0.9973	0.9967	0.9986	1.0000	0.9993	0.9998	0.9997	0.9999	0.9999	1.0000	1.0000	1.0000
I	0.8933	0.9269	0.9997	1.0000	0.9932	0.9972	0.9978	0.9993	0.9994	0.9991	0.9997	0.9998	0.9996	0.9998	1.0000	1.0000	1.0000
J	0.9077	0.9596	0.9965	0.9737	0.9859	0.9940	0.9988	0.9999	0.9996	0.9997	0.9998	0.9994	0.9997	0.9999	1.0000	1.0000	1.0000

Table 18 Integrated utility functions value

3PRLP	Final *Qi*	Final *Pi*	Assessment value	Ranking
A	−0.164	6.945	3.390	9
B	−0.065	7.090	3.513	2
C	−0.086	7.062	3.488	7
D	−0.134	6.993	3.372	10
E	−0.084	7.066	3.491	6
F	−0.081	7.067	3.493	5
G	−0.075	7.071	3.498	4
H	−0.124	6.999	3.437	8
I	−0.019	7.166	3.573	1
J	−0.072	7.081	3.505	3

Table 19 Comparative ranking of alternatives for reverse logistics providers

3PRLSPs	MOORA	WASPAS
A	6	9
B	2	2
C	5	7
D	10	10
E	8	6
F	9	5
G	7	4
H	4	8
I	1	1
J	3	3

6 Conclusions

MOORA and WASPAS method ranking give service provider I as the best alternative for automobile industry in management of sustainable supply chain. MOORA method ranks alternative by comparing each of the criteria with other alternative and finally finds the assessment value based on normalize data. It also considers into account the weightage given by SWARA method. WASPAS method works on a pair-wise comparison method of alternatives in each single criterion in order to regulate partial relations denoting the preference of an alternative over the other. Ranking by MOORA considering a linear preference function gives the same results as ranking by WASPAS. The similar results are obtained using decision-making framework model. MOORA and WASPAS method are consistent with the discussion. The effect of parameter λ on the ranking enactment of WASPAS method is also studied, revealing the fact that better results are attained at higher value of λ values.

When the value of λ is set at 0, WASPAS method works like a WPM method, and when λ is 1, it is transformed into WSM method. The main advantage of this method is identified as its strong resistance against rank reversal of the considered alternatives. It is also found that this method has the unique capability of dealing with both single and multi-response optimization problems in various machining operations.

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