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A NOVEL MCDM MODEL FOR WAREHOUSE LOCATION SELECTION IN SUPPLY CHAIN MANAGEMENT

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Abstract: *The present investigation reveals a novel method for the evaluation of warehouse location for leagile supply chain entailing Fuzzy Multi Criteria Analysis (FMCA). An attempt has been made to apply the concept of decision theory for selecting the warehouse under contradictory criteria. Aggregate Modified Weighted Value (MWV) of normalized score of alternative is determined to evaluate Benefit Cost Ratio (BCR) which is considered as the warehouse selection index. The proposed algorithm is illustrated with a suitable numerical example to adjudge its desirable importance in capability and practicability. It also ensured that the achieved result clearly matches with those of previous research works. Finally, sensitivity analysis has been carried out that justify and supports the application of proposed algorithm in finding the most favorable outcome to the selection problem of warehouse location.*

Key words: *Leagile supply chain, Warehouse location selection, FMCDM, Benefit cost ratio.*

1. Introduction

Supply chain is a system of association concerned with upstream, mid-stream and downstream link in diverse procedure and actions so as to create value in terms of services and products for customer satisfaction (Lee & Billington, 1992). The center of attention of the lean manufacturing has basically been on the diminution or abolition of waste. Lean is concerning doing extra with a smaller amount. The concept of lean work well if demand is predictable and stable and if variety is small (Agarwal et al., 2006). On the other hand for unpredictable demand and additional varieties of customer's requisite, a higher level of agility is necessary (Lee, 2002).

The objective of a supply chain is to exploit the value produced and robustly interrelated through effectiveness of supply chain. The ultimate achievement and profitability of a business depends on proper planning, appropriate design and suitable operation of a supply chain. The effectiveness of a usual supply chain largely

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is affected by the transportation, inventory, information and facilities (Chopra & Meindl, 2001), proximity to customers and markets, suppliers' availability, and even social issues as the potential stability for the warehouse location selection (Heizer & Render, 2004; Stevenson et al., 2007).

Ocampo et al. (2020) applied group TOPSIS for selection of warehouse location considering diverse allocations of expert priority. Ulutaş et al. (2021) introduced a novel combined Grey based MCDM approach in selection of ware house location. Micale et al. (2019) advocated an integrated TOPSIS with interval-valued ELECTRE TRI method for appropriate decision making in storage location problem. Kabak and Keskin (2018) used multi-criteria decision making and GIS approach for selection of warehouse for storing hazardous materials. Dey et al. (2017) introduced and applied an MCDM model with group heterogeneity for selection of the best warehouse location.

Pang and Chan (2017) employed a data mining based new step by step algorithm foe assignment of storage location in warehouse. Emeç and Akkaya (2018) applied stochastic analytical hierarchy process combining with fuzzy VIKOR method for the purpose of right decision making in appropriate warehouse location selection under MCDM environment.

The analysis of the gap of the above literature survey exposes that previous researchers have applied MCDM techniques for selection of warehouse location. But this endeavor is not enough for exhaustive and wide decision making regarding proper selection of warehouse location. Thus an attempt in the current investigation is made to suggest a novel method for the evaluation of warehouse location for leagile supply chain entailing Fuzzy Multi Criteria Analysis (FMCA).

The current paper has objective of improving the warehouse location selection techniques by using the concept of decision theory. The proposed algorithm has been employed to choose the top warehouse location amongst a set of realistic alternatives. The result of this novel algorithm is compared with works of past researchers on the identical problem. Lastly, an appropriate example is solved to illustrate the proposed algorithm. This investigation proves that the proposed algorithm is compatible for selection of multidimensional warehouse location problem. The current study also enhances the models used for the same.

The paper is organized as follows. Section 2 presents a revision on he fuzzy set theory. Section 3 is dedicated for the proposed algorithm. In the section 4, an appropriate example is cited and solved. Sensitivity analysis is conducted in section 5. Section 6 explores the significance of the results of the work and section 7 presents some significant concluding remarks on the proposed model.

2. The Fuzzy Set Theory

Decision makers usually have a preference subjective to objective assessment of fuzzy information. Theory of fuzzy set is used to convert these subjective data into numerical (objective) values (Chiou et al., 2005). A number of important definitions on fuzzy set are presented in the following subsection 2.1.

2.1. Some Important Fuzzy Definitions

Definition 1: A fuzzy set $\tilde{A}$ is defined in a universe of discourse denoted by X specified by $\mu_{\tilde{A}}(x)$, called membership function, which connects every member x (a real number) in *X* in a interval where x belong to [0, 1]. (Zadeh, 1965; Dubois & Prade, 1978).

Definition 2: A Triangular Fuzzy Number (TFN) $\tilde{q}$ is defined as a triplet (q_1, q_2, q_3). Membership function is characterized as follows (Chu, 2002; Keufmann & Gupta, 1991).

$$\mu_{\tilde{q}}(x) = \begin{cases} 0, & x < q_1 \\ \dfrac{x-q_1}{q_2-q_1}, & q_1 \le x \le q_2 \\ \dfrac{x-q_3}{q_2-q_3}, & q_2 \le x \le q_3 \\ 0, & x > q_3. \end{cases} \quad (1)$$

Membership function of a TFN $\tilde{q} = (q_1, q_2, q_3)$ is graphically shown in Figure 1.

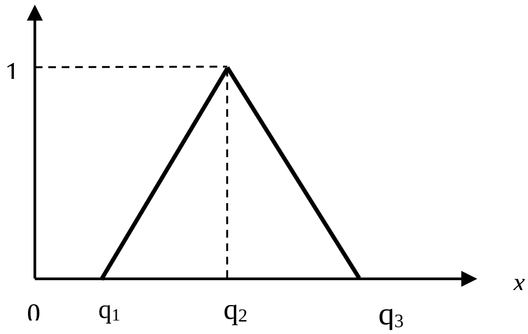

Figure1. Membership function of a TFN $\tilde{q} = (q_1, q_2, q_3)$

Definition 3: Let $\tilde{q} = (q_1, q_2, q_3)$ and $\tilde{r} = (r_1, r_2, r_3)$ be two TFNs, then the distance between the two fuzzy numbers can be calculated as

$$d(\tilde{q}, \tilde{r}) = \sqrt{\frac{1}{3}\left[(q_1 - r_1)^2 + (q_2 - r_2)^2 + (q_3 - r_3)^2\right]}$$

This method of calculating distance between two fuzzy numbers is termed as vertex method (Klir & Yuan, 1995).

2.2. Fuzzy Operations

Let $\tilde{q} = (q_1, q_2, q_3)$ and $\tilde{r} = (r_1, r_2, r_3)$ are two triangular fuzzy numbers.

(a) Addition: $\tilde{q} \oplus \tilde{r} = (q_1 + r_1, q_2 + r_2, q_3 + r_3)$

(b) Multiplication of a fuzzy number $\tilde{q} = (q_1, q_2, q_3)$ with a real number k

$k \otimes \tilde{q} = (kq_1, kq_2, kq_3)$ where $k \ge 0$ & $k \in R$

(c) Multiplication commutative property $k \otimes \tilde{q} = \tilde{q} \otimes k$ where $k \ge 0$ & $k \in R$.

(d) Division of a fuzzy number $\tilde{q} = (q_1, q_2, q_3)$ with a real number k

$\tilde{q}(\div)k = \left(\frac{q_1}{k}, \frac{q_2}{k}, \frac{q_3}{k} \right)$ Where $k \geq 0$ & $k \in R$ (Dubois & Prade, 1978).

3. Proposed Algorithm

A multi-criteria decision-making procedure has been applied for the evaluation of the most excellent warehouse location among various suitable alternatives. A quantitative approach of decision theory has been utilized in order to improve the selection procedure of warehouse location. The steps of the process of the newly proposed algorithm have been furnished below.

Step 1: Formation of decision making committee: The committee unanimously chooses effective criteria and selects the alternatives preliminarily. Let, D_1, D_2...D_p are the decision-makers; C_1, C_2... Cn are the selected criteria; where number of benefit criteria is 'b' and that of cost criteria is 'c'such that $(b+c)=n.$ and A_1, A_2... A_m are initially selected warehouse locations.

Step 2: Formation of decision matrix: The committee makes a short list of alternative warehouses for further assessment on the basis of the selection criteria. Each alternative warehouse is given a score by the committee (or each member of the committee) with respect to each attribute; this score is termed as performance rating or simply rating. Performance ratings under objective criteria are expressed in crisp (specific) values and under subjective criteria are expressed in linguistic terms due to vagueness, imprecision, and ambiguity. The words or phrases like 'good', 'very good', 'medium', 'poor', 'very poor' etc. are called linguistic variables which are measured by human perception, feelings, experience etc. A decision matrix with m number of alternatives, $\left[A_1 \;\; ... \;\; A_i \;\; ... \;\; A_m\right]^T$, $(C_1 \;\; \cdots \;\; C_j \;\; \cdots \;\; C_n)$ where n is criteria number.

$$[DM]_{m\times n} = \begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{matrix} C_1 & \ldots & C_j & \ldots & C_n \end{matrix} \\ \begin{bmatrix} x_{11k} & \cdots & x_{1jk} & \cdots & x_{1nk} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1k} & \cdots & x_{ijk} & \cdots & x_{ink} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1k} & \cdots & x_{mjk} & \cdots & x_{mnk} \end{bmatrix} \end{array} \tag{2}$$

x_{ijk} is performance rating in linguistic variable which is converted into fuzzy number x_{ijk} where, $\tilde{x}_{ijk} = \left(a_{ijk}, b_{ijk}, c_{ijk}\right)$ or $\tilde{x}_{ijk} = \left(a_{ijk}, b_{ijk}, c_{ijk}, d_{ijk}\right)$ is the performance rating of i[th] candidate (alternative) for j [th] factor (criterion) given by k[th] decision maker.

Step 3a: Formation of weight matrix: the committee members give diverse importance to the criteria in linguistic variables according to their knowledge and experience. Each linguistic variable is changed into corresponding TFN. The weight matrix is presented in Eq. (3).

$$W = \begin{array}{c} \\ C_1 \\ \cdots \\ C_j \\ \cdots \\ C_n \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & \cdots & C_j & \cdots & C_n \end{array} \\ \begin{bmatrix} w_{11} & \cdots & w_{1k} & \cdots & w_{1p} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ w_{j1} & \cdots & w_{jk} & \cdots & w_{jp} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ w_{n1} & \cdots & w_{nk} & \cdots & w_{np} \end{bmatrix} \end{array} \quad (3)$$

Here $w_{jk} = (\alpha_{jk}, \beta_{jk}, \gamma_{jk})$ or $w_{jk} = (\alpha_{jk}, \beta_{jk}, \gamma_{jk}, \delta_{jk})$ is the importance weight of j^{th} (factor) criterion awarded by the k^{th} (experts) decision maker in fuzzy numbers (triangular or trapezoidal) respectively

Step 3b: Defuzzification and average weight: For decision-making committee, the defuzzified average weight of the criteria is considered. Defuzzified average weight of each criterion is calculated by using Eq. 4(a) for triangular fuzzy number or Eq. 4 (b) for trapezoidal fuzzy number.

$$\overline{w}_j = \frac{1}{3P}\sum_{k=1}^{P}(\alpha_{jk} + \beta_{jk} + \gamma_{jk}) \quad 4(a)$$

$$\overline{w}_j = \frac{1}{4P}\sum_{k=1}^{P}(\alpha_{jk} + \beta_{jk} + \gamma_{jk} + \delta_{jk}), \text{ j = 1, 2... n.} \quad 4(b)$$

Step 3c: Normalization of weight: Normalization process of defuzzified average importance weight of each criterion is accomplished by Eq. 4(c).

$$\overline{w}_j^N = \frac{\overline{w}_j}{\sum_{j=1}^{n}\overline{w}_j}, \quad \text{j = 1, 2, 3,... ,n.} \quad 4(c)$$

Step 4a: Defuzzification and average rating: Determination of defuzzified average performance rating of every alternative for every subjective criterion by following Eq. (5a) for triangular fuzzy number or Eq. (5b) for trapezoidal fuzzy number. Average ratings for the objective criteria are calculated by the Eq. 5(c).

$$\overline{x}_{ij} = \frac{1}{3P}\sum_{k=1}^{p}\left(a_{ijk} + b_{ijk} + c_{ijk}\right) \quad 5(a)$$

$$\overline{x}_{ij} = \frac{1}{4P}\sum_{k=1}^{p}\left(a_{ijk} + b_{ijk} + c_{ijk} + d_{ijk}\right) \quad 5(b)$$

$$\overline{x}_{ij} = \frac{1}{P}\sum_{k=1}^{p}\left(x_{ijk}\right) \quad 5(c)$$

Step 4b: Normalization of rating: Average rating of each alternative is normalized using Eq. (6).

$$\overline{x}_{ij}^N = \frac{\overline{x}_{ij}}{\sum_{i=1}^{m}\overline{x}_{ij}} \quad (6)$$

Step 5: Calculation of modified weighted values: In this method, modified weighted normalized rating is advocated for the assessment of alternative for each benefit and non-benefit criterion**.** Performance weight replaces both interest factor as well as time period under consideration. The benefit of using importance weight in its place of both interest rate and time period is that the computed coefficient of normalized rating provides a modified weight which depends upon corresponding weight. Modified-weighted benefit and non benefit criteria value is calculated using Eq. (7) and Eq. (8) respectively.

$$mwv_{ij}^{B} = x_{ij}^{N} / \left(1-\overline{w}_{j}^{N}\right)^{\overline{w}_{j}^{N}} \tag{7}$$

$$mwv_{ij}^{C} = x_{ij}^{N} / \left(1-\overline{w}_{j}^{N}\right)^{\overline{w}_{j}^{N}} \tag{8}$$

mwv_{ij}^{B} = Modified weighted value of normalized rating of alternative i under benefit criterion j, mwv_{ij}^{C} = Modified weighted value of normalized rating of alternative i under cost criterion j, $\overline{x}_{ij}^{N}$ = Corresponding normalized rating of alternative i under criterion j, $\overline{w}_{j}^{N}$ = Corresponding importance weight of jth criterion.

Weight of criteria has been modified using the Eq. (7) and Eq. (8) respectively. Here importance weight ($\overline{w}_{j}^{N}$) is simultaneously an analogue to the interest rate and number of periods of cash flows in finding the future value in engineering economy. So, the weight of criteria successfully replaces discounted rate (or interest rate) and time period. The value so obtained will be termed as modified weighted value throughout the paper. This modified weighted value is multiplied with normalized rating in order to obtain the modified normalized rating which gives the measurement of benefit or cost.

Step 6: Aggregate modified weighted value*:* Modified weighted values of ratings under benefit criteria and cost criteria are separately added for calculating aggregate modified-weighted value. Aggregate modified-weighted Value under benefit criteria and cost criteria reflect the assessment of total beneficial scores and cost scores respectively. Aggregate modified-weighted Values are calculated using the following simple Eq. (9) and Eq.(10) respectively.

$$AMWV_{i}^{B} = \sum_{j=1}^{b} x_{ij}^{N} / \left(1-\overline{w}_{j}^{N}\right)^{\overline{w}_{j}^{N}} \tag{9}$$

$$AMWV_{i}^{C} = \sum_{j=1}^{c} x_{ij}^{N} / \left(1-\overline{w}_{j}^{N}\right)^{\overline{w}_{j}^{N}} \tag{10}$$

$AMWV_{i}^{B}$ = Aggregate modified weighted value of alternative i for all benefit criteria. $AMWV_{i}^{C}$ = Aggregate modified weighted value of alternative A_i for all cost criteria.

Step 7: Benefit-Cost Ratio (BCR): In this paper, benefit-cost ratio is proposed to consider warehouse selection index. Benefit-cost ratio of an alternative is expressed by the ratio of aggregate modified weighted value of ratings under benefit criterion to that of the cost criterion. The higher value of Benefit Cost Ratio is desirable. The following Eq. (11) is used for calculating Benefit Cost Ratio (BCR) of i^{th} alternative.

$$\left(BCR\right)_{i} = \left(MWV_{i}^{B} / MWV_{i}^{C}\right) \tag{11}$$

The higher the benefit cost ratio is, the better the alternative is.

Step 8: Selection: The alternative warehouses are arranged in order of decreasing benefit cost ratio. Higher benefit-ratio is desirable. The best warehouse is one which has the highest benefit cost ratio. Similarly the worst warehouse is one which is which attains the least benefit cost ratio.

The above algorithm is applied to solve a warehouse location selection problem and to demonstrate implementation of the paradigm.

4. Illustrative Example Demonstrating Proposed Algorithm

The proposed algorithm has been illustrated with an example. This has been presented dividing it into two sub-sections: Warehouse location selection problem definition, calculation and discussions.

4.1 Warehouse Location Selection Problem Definition

The proposed algorithm has been demonstrated with an example on warehouse location selection. The objective is to develop a process for the combination of different criteria pertinent to selection of warehouse location with a view to obtain a comprehensive ranking order of the alternative warehouses. The example on warehouse location selection has been cited from Chen et al. (2006). In the present example, a homogeneous decision-making committee is composed of three decision-makers or experts namely D_1, D_2 and D_3. Each members of the homogeneous decision making committee has equal importance weight. Through a screening test, the committee preliminarily takes three alternatives warehouse locations A_1, A_2 and A_3 under consideration of further assessment. The committee also considers five subjective decision criteria viz. Cost (C1), Possibility of expansion (C2), Availability of required material (C3), Human resource (C4) and Proximity to market (C5).

4.2 Calculation and Discussions

Owing to subjective, vague and imprecise, the performance ratings of the alternatives are with respect to all the five criteria are estimated by linguistic variables. Linguistic variables are easy use and understand. Linguistic variables requires less efforts and less time with compared to other mode of expression. That is why decision makers prefer linguistic variables to objective measurement. In the current problems decision makers uses seven degrees of linguistic variables to express their assessment and perception regarding the alternative warehouse locations towards the criteria. The seven degrees of linguistic variables used for expressing performance ratings, their respective acronyms and the corresponding triangular fuzzy numbers have been accommodated in Table 1.

The degree of importance weights of various criteria in decision making on proper selection of warehouse location varies from criterion to criterion and decision maker to decision makers. The decision makers involved in the decision making process are inspired to use a common set of seven degrees of linguistic variables for measuring importance weights of the criteria.

Table 1. Linguistic variables with fuzzy numbers for ratings

Linguistic variables	Acronym	Fuzzy numbers
Extremely Poor	V P	(0, 0, 1)
Poor	P	(0, 1, 3)
Slightly Poor	M P	(1, 3, 5)
Fair	F	(3, 5, 7)
Medium Good	M G	(5, 7, 9)

Good	G	(7, 9, 10)
Extremely Good	V G	(9, 10, 10)

Source: Chen et al. (2006)

The seven degrees of linguistic variables used for expressing importance weights, their respective acronyms and the corresponding triangular fuzzy numbers have been arranged in Table 2.

Table 2. Linguistic variables, Acronyms and TFN for the estimation of weight

Linguistic variables	Acronym	Fuzzy Numbers
Very low	VL	(0, 0, 0.1)
Low	L	(0, 0.1, 0.3)
Medium Low	ML	(0.1, 0.3, 0.5)
Medium	M	(0.3, 0.5, 0.7)
Medium High	MH	(0.5, 0.7, 0.9)
High	H	(0.7, 0.9, 1.0)
Very high	VH	(0.9, 1.0, 1.0)

Source: Chen et al. (2006)

The decision makers estimate the weights of criteria in linguistic variables and are represented in Table 3.

Table 3. The linguistic weight of the criteria.

Criteria	D_1	D_2	D_3
C_1	H	VH	VH
C_2	H	H	H
C_3	MH	H	MH
C_4	MH	MH	MH
C_5	H	H	H

Source: Chen et al. (2006)

Since the criteria have different dimensions, they are normalized in order to convert into dimensionless quantity so as to compare one another. Defuzzified average values of weight are calculated using Eq. 4(a). Normalized weights are calculated using Eq. 4(c). Defuzzified and normalized values of weights are shown in Table 4.

Table 4. Defuzzified and normalized weight of the criteria

Values	C_1	C_2	C_3	C_4	C_5
Defuzzified values	0.93	0.87	0.75	0.70	0.87
Normalized values	0.226	0.21	0.182	0.17	0.211

Performance rating of each warehouse is estimated by the each decision makers with respect to each criterion which are estimated by the knowledgeable decision makers. Cost criteria are expressed in numerical values. And the remaining four criteria are evaluated by prescribed linguistic variables in specified degrees. It can be easily observed that the performance ratings of the warehouse A1, A2, and A3 with respect to criterion C1 by the decision maker D1 are 6, 3, 4 million respectively. The linguistic variables for the alter natives A1, A2, and A3 estimated by decision maker D1 with respect to criterion C2 are expressed as G, EG, and MG respectively. The linguistic variables for the alter natives A1, A2, and A3 estimated by decision maker

D2 with respect to criterion C2 are expressed as EG, EG, and G respectively. The remaining performance rating of the three alternative warehouses with respect to the criteria as assessed by the decision makers are provided in the following Table 5.

Table 5. Performance ratings of the warehouses by the decision makers

Criteria	Alternative	D1	D2	D3
C1	A1	6 (million)	8 (million)	7 (million)
	A2	3 (million)	4 (million)	5 (million)
	A3	4 (million)	5 (million)	6 (million)
C2	A1	G	E G	F
	A2	E G	E G	E G
	A3	M G	G	E G
C3	A1	F	G	G
	A2	G	G	G
	A3	G	S G	E G
C4	A1	EG	G	G
	A2	G	G	G
	A3	G	E G	E G
C5	A1	F	F	F
	A2	G	F	G
	A3	G	G	G

Source: Chen et al. (2006)

Average and normalized values of rating of objective criteria as well as defuzzified and normalized values of rating of alternatives under subjective criteria are shown in Table 6. The normalized decision matrix is represented in Table 7.

Table 6. Average normalized rating of objective criteria and defuzzified normalized rating of subjective criteria

	C_1		C_2		C_3		C_4		C_5	
Alternative	AV	NV	D V	N V	D V	N V	D V	N V	D V	NV
A_1	7	0.4375	8.0	0.3052	7.44	0.3032	9.00	0.3335	5.00	0.237
A_2	4	0.25	9.66	0.3686	8.66	0.3529	8.66	0.3209	7.44	0.3526
A_3	5	0.3125	8.55	0.3262	8.44	0.3439	9.33	0.3457	8.66	0.4104

AV= Average value, DV =Defuzzified Values, NV =Normalized values

Modified weighted normalized rating is calculated. For example, modified weighted value of alternative A_1 for benefit criterion C_2 (expansion possibility) is computed as $mwv_{12}^{B} = 0.3052/(1-0.21)^{0.21} = 0.3206$. Modified weighted value of alternative A_1 for cost criterion C_1 (investment cost) is computed as $mwv_{11}^{C} = 0.4375/(1-0.226)^{0.226} = 0.4636$. Aggregate modified weighted ratings are determined. For alternative A_1 for benefit criteria (C_2, C_3, C_4, C_5) , the calculation process is

$$AMWV_1^{B} = \left(mwv_{12}^{B} + mwv_{13}^{B} + mwv_{14}^{B} + mwv_{15}^{B}\right) = \left(0.3206 + 0.3145 + 0.3442 + 0.2491\right) = 1.228$$

Table 7. Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5
Weight →	0.226	0.21	0.182	0.17	0.211
A_1	0.4375	0.3052	0.3032	0.3335	0.237
A_2	0.25	0.3686	0.3529	0.3209	0.3526

A3	0.3125	0.3262	0.3439	0.3457	0.4104

The modified weighted values and aggregate modified weighted values are determined and presented in Table 8.

Table 8. Modified weighted values, Aggregate modified weighted values

	Modified weighted values					Aggregate modified weighted values	
Alternatives	mwv_{i1}^{C}	mwv_{i2}^{B}	mwv_{i3}^{B}	mwv_{i4}^{B}	mwv_{i5}^{B}	$AMWV_{i}^{C}$	$AMWV_{i}^{B}$
A1	0.4636	0.3206	0.3145	0.3442	0.2491	0.4636	1.228
A2	0.2649	0.3873	0.3660	0.3312	0.3706	0.2649	1.455
A3	0.3311	0.3427	0.3671	0.3568	0.4314	0.3311	1.498

Benefit-Cost Ratio (BCR) is calculated by using Eq. (11)., BCR for alternative A_1 is calculated as $(BCR)_1 = \left(AMWV_1^B / AMWV_1^C\right) = (1.228/0.4636) = 2.6488$.

Benefit-cost ratios and the ranking order of the alternative warehouse locations are accommodated in Table 9.

Table 9. Benefit–cost ratio and ranking order of the alternatives

Alternatives	Benefit-Cost ratio	Ranking order
A1	2.6488	3
A2	5.4926	1
A3	4.5243	2

The final ranking of the alternatives is decided on the basis of benefit cost ratio vs. alternatives. The ranking orders of the warehouse locations under consideration are graphically depicted in Figure 2, for achieving higher visibility and clarity.

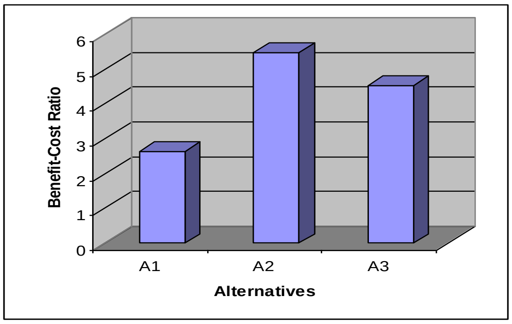

Figure 2. Benefit cost ratio of alternatives warehouse locations

The graphical representation clearly shows that the ranking order of the warehouse locations as per the proposed method is $A_2>A_3>A_1$. The best warehouse location is A_2. A comparison of the results obtained by the proposed approach with those of past researches available in the open journals has been made and shown in Table 10.

Table 10. Comparison of results (Ranking) among various papers

Alternatives	Chen et al. (2006)	Proposed method
A 1	3	3
A 2	1	1
A 3	2	2

5. Sensitivity Analysis

A sensitivity analysis of the problem of warehouse location selection has been carried out and the result has been depicted in Figure 3. The sensitivity analysis is the graphical representation of benefit cost ratio of warehouses with respect to variable decision making attitude. The following Eq. (12) governs the warehouse selection index in sensitivity analysis.

$$WSI_i = MWV_i^{B*}\alpha + (1-\alpha)MWV_i^{C*} \qquad (12)$$

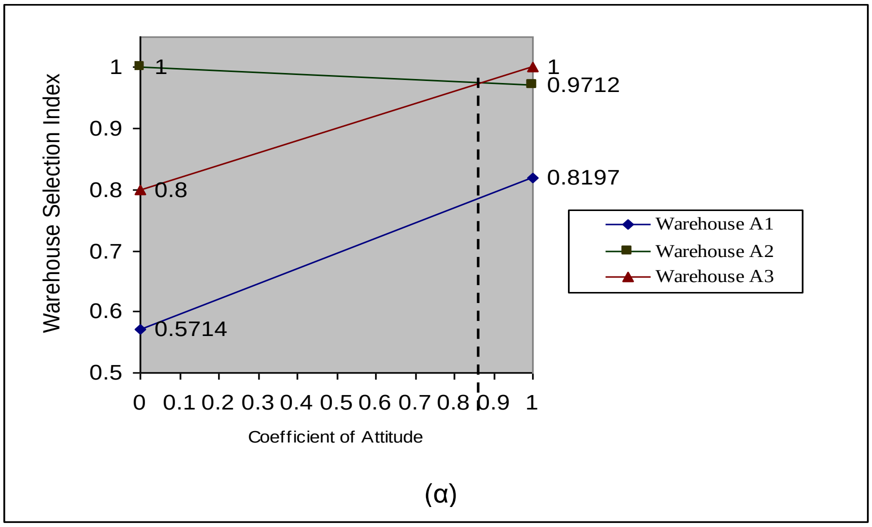

Figure 3. Sensitivity analysis of selection index with respect to coefficient of attitude

MWV_i^{B*} and MWV_i^{C*} are aggregate normalized value and Modified Weighted value of alternative i for benefit and cost criteria respectively. α = Coefficient of decision making attitude in the range $0 \le \alpha \le 1$.The sensitivity plot clearly shows that warehouse location 2 has the maximum BCR in the range of $0 \le \alpha \le 0.87$.The result of the sensitivity plot in the range of $0 \le \alpha \le 0.87$ is also in line with the ranking order of warehouse locations. But warehouse location 3 has the highest benefit cost ratio while $0.87 \le \alpha \le 1$ which is shown in Table 11. The sensitivity analysis gives a readymade and prompt solution to the current problem under unpredictable coefficient of decision attitude.

Table 11. Sensitivity analysis

Option	Range of coefficient of attitude(α)	Selection of Warehouse
1.	0 ≤ α < 0.87	Select A_2
2.	0.87 < α ≤ 1	Select A_3
3.	α = 0.87	Indifferent towards A_2 & A_3

6. Discussions

The concept of lean is well applicable where demand is comparatively steady and predictable with low variety. On the other hand, for unstable demand and varieties of customer's need, to a large extent of higher level "agility" is necessary. The leagile supply chain integrates the lean and agile paradigms contained by a total supply chain approach by placing the decoupling point for the best suit of the need. The decision making in the leagile supply chain is very intricate in nature. The approach proposed in the paper is an aid to the managers for correct decision for the leagile supply chain. The proposed algorithm recommends the benefit cost ratios as the selection criteria of warehouse location. Accordingly, the warehouse locations are ranked as follows:

$A_2 > A_3 > A_1$

It is observed that A_2 is the best warehouse location. It has also been revealed that the ranks of warehouse locations found by applying the proposed algorithm that employs the proposed methodology produces the similar result obtained by past researchers using different method as shown in Table 9. The method validates the judgment behind the approach which complies with the technique adopted by the researchers as demonstrated in literature survey. The proposed algorithm has a number of significant features as follows:

a. The modification of weight in the proposed algorithm is exclusive in nature.
b. It is able of managing fuzziness of the decision making environment.
c. The method is capable of considering subjective and objective criteria to select the best warehouse location.
d. The algorithm is simple, easier and straightforward.

7. Conclusions

Lean supply chain is capable of maximizing profit through waste reduction whereas agile supply chain maximizes profit by delighting the customers. Leagility in the supply chain makes the upstream cost effective whereas the downstream becomes more service oriented. In this paper, the algorithm has incorporated the concept of modified weighted value into the decision theory for the selection of warehouse in a supply chain which may be very handy for the decision makers. This paper gives a revised version of weight avoiding direct use by employing engineering economy. This modification of weight has not yet been reported in any research work. The consistency of results of the cited problem with those of other works strongly justifies the concept of modification of weight. Benefit cost ratio is considered as the key selection parameter for warehouse location selection. The importance weight of criteria play a great role in the evaluation process as it simultaneously act as the interest rate and number of periods of cash flows.

This algorithm is simple, easier and capable of considering fuzziness. This new method may be thought of an extended version of simple additive weighting (SAW) method with modified weight applying engineering economy or financial management. This approach is appropriate for implementation in other managerial decision making problems. By transforming it into computerized algorithm, a large number of criteria, alternatives, and decision makers' view can be considered.

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