An Induced Fuzzy Rasch-Vikor Model for Warehouse Location Evaluation under Risky Supply Chain

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Abstract. This paper addresses dynamic risky nature of supply chain in warehouse site evaluation where the target is to design network flow of products so that all customers demands are satisfied at minimum risk in distribution network. Main theme of the paper is to choose the most optimal and low risk warehouse spot from a number of potential alternatives locations. A new Fuzzy- Rasch-VIKOR decision model is provided where uncertain information are exploited getting group of decision makers as multiple experts providing decision through triangular fuzzy numbers. A two-phase algorithmic approach is proposed to deal with the problem. First phase involves identification of warehouse location, evaluation of risk criteria using fuzzy Rasch model to quantify criteria weights under uncertainty and second phase ranks the location alternative by fuzzy- VIKOR method for selecting the optimal low risk site. Finally we demonstrate our decision model with a case study illustrating the application in risky supply-chain.

Keywords: Fuzzy Rasch Model, VIKOR, Multiple criteria decision making (MCDM), Supply chain risk management (SCRM).

1 Introduction

Evaluation of warehouse location in a complex supply chain is a typical multiattribute based decision making problem having various risk criterias. A poor choice of location may result in lower logistic performance, minimal usage of resources and loss of competitive advantage in market. In supply chain management, warehouse function as consolidation points where products shipments from production sites are assembled or sorted. In supply chain warehousing selection, many methods were proposed by researchers in past years. Chen [1] presented a fuzzy MCDM problem for location of distribution center. Hidaka and Okano [2] determined a simulation method for selection of hefty warehouse location. Michel and Hentenryck [3] put forward a tabulated search algorithm using linear neighborhood on incapacitated warehouse location problem. Sharma and Berry [4]

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gave an idea of locating single-stage computed warehouse. Opricovic [5] developed complex multi-criteria optimization using Ideal point VIKOR. Andrich [6] developed Rating Scale Model and adopted five-point Likert scale in parameter evaluation and generating fuzzy numbers. Yu and Wu [7] utilized the Rasch Item Response Theory to evaluate fuzzy elements. Huang and Peng [8] combined Rasch model, fuzzy logic and TOPSIS method to access competition in Asian region tourism sector. This study proposes a new hybrid model, the fuzzy Rasch model in VIKOR combining Rasch model, fuzzy theory and VIKOR, which is discussed below. The above model is applied in warehouse selection for a global electrical manufacturer company, from among eight location alternatives in India taking into account various risks in supply chain.

2 Basic Concepts

2.1 Rasch Model

Rasch Models, also known as One-Parameter Logistic and static model under Item response theory (IRT) models in field of psychometry quantifying human behaviour. Rasch Model was developed for two choice items. It models the relationship between person's ability and item difficulty as probabilistic function. Correct data are obtained based on degree of latent proficiency function. Measuring in logits (log odd units) the model converts initial raw data from rating scale to equal interval scale showing both difficulty of item and individual ability. Rasch model provides the fuzzy perception logic model with precise properties far comprehensive to fuzzy logic.

2.2 Rating Scale Model

Andrich [6] who developed Rating scale model (RSM), is a additive linear model describing probability of response of specific person (n) to specific Likart item (i) with specific rating scale step (x). RSM applies Rasch model to polytomous rating scale instruments, including five-point Likart scale. RSM is applied to assess the values of parameters, shown as: $\log\{P_{nij}/P_{ni(j-1)}\} = \theta_i - (\delta_i + \tau_j)$ where P_{nij} = probability the item n obtain j scores from expert i; $P_{ni(j-1)}$ = probability the item n obtain j-1 scores from expert i; θ_i = item difficulty of item n; δ_i = individual ability of expert i; τ_j = step difficulty of category j.

2.3 Vikor Model

The VIKOR [5] (Viekraterijumsko KOmpromisno Rangi ranje) method was proposed by Opricovic for multi-criteria based methodology in complex Network process based on ideal point method. It evaluates the ranking list, comprehensive solution and weight stability intervals for preference alternatives in respect to initial (given) weights. Based on ranking index it determines closeness of given data to ideal solution. By introducing multi-criteria index based

on measure of closeness to ideal solution compromising ranking list and solution are evaluated. VIKOR method developed in form of L_p metric. $L_{p,i} = \{\sum_{j=1}^n \{w_j(f_j^* - f_{ij})/(f_j^* - f_j^-)\}^p\}^{1/p}$, $1 \leq p \leq \infty$, $i = 1, 2, \dots, m$. In VIKOR model, $L_{1,j}$ (as S_i) and $L_{\infty,j}$ (as R_i) are applied in ranking measurement. The solution gained by min S_i and by min R_i is with a maximum group utility of the majority, and minimum individual regret of opponent respectively.

3 Algorithmic Approach to Fuzzy-Rasch Based VIKOR Model

For the function of risk criteria in selection of warehouse location, our proposed model uses Fuzzy Rasch method to propagate the triangular fuzzy weights of the risky criteria. Then defuzzified fuzzy weights are then applied in Fuzzy VIKOR for ranking the optimal warehouse location zones. The algorithmic steps are as follows:

Step 1: Risk criteria and the corresponding alternatives are evaluated based on decision makers judgment.

Step 2: Based on Fuzzy Rasch Model the weights of the risk criteria are generated.

2.1 Step parameters (δ_{ij}) for determining fuzzy weight are calculated based on decision-makers importance for each criterion. Using triangular fuzzy weight and arithmetic average to evaluate the fuzzy weight of each expert, $\tilde{W}_C = (\delta_c^L, \delta_c^M, \delta_c^U)$.

2.2 The fuzzy criteria weights are transform into crisp weights through defuzzification, done by best on Non-fuzzy performance value, $BNP_c = (\delta_c^L + \delta_c^M + \delta_c^U)/3$, which are used as criteria weights in VIKOR. Based on above, this study standardize the weights W_c of criterion, $SBNP_c$; $W_c = SBNP_c = BNP_c / \sum_{c=1}^c BNP_c$ where c represent the number of criteria.

Step 3: A decision matrix is formed based on calculated values of alternatives with respect to each criteria. The defuzzified values of criteria to the alternatives are calculated.

Step 4: Determine the best f_i^* and worst f_i^- values of all criteria functions, for i^{th} risk criteria function, $f_i^* = \min_j f_{ij}$ and $f_i^- = \max_j f_{ij}$.

Step 5: Compute the values of S_j , R_j and Q_j , $j = 1, 2, \dots, J$ by the relations $S_j = \sum_{i=1}^n w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)$, $R_j = \max_j w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)$, $Q_j = \frac{v(S_j - S^*)}{(S^- - S^*)} + \frac{(1-v)(R_j - R^*)}{(R^- - R^*)}$, $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, $R^- = \max_j R_j$ where w_i = weights of criteria and v = weight of maximum group utility.

Step 6: Based on values of S_j , R_j and Q_j , ($j = 1, 2, \dots, J$); final ranking of alternatives is proposed.

Step 7: Alternative (a') is ranked the best by measure Q (minimum): $Q(a'') - Q(a') \geq DQ$ where (a'') is second best alternative by Q: $DQ = 1/(J - 1)$ where J is the number of alternative and alternative (a''), must also be best ranked by S or/and R. The best alternative, ranked by Q, is the one with minimum value of Q. The main ranking result is the compromise ranking list of alternatives.

4 Case Study

Havell's India Ltd, a billion-dollar-plus power distribution equipment manufacturer organization has 94 branches and over 8000 professionals in over 50 countries across the globe. It plans to select new warehouse in India to improve its work productivity following ten risk Criteria are under consideration: Political Instability risk (C_1); Environmental risk (C_2); Market demand and sale risk (C_3); Logistics and cargo damage risks (C_4); Natural calamities risk (C_5); Inflation rate risk (C_6); Custom delays and damage risk (C_7); Information flow and affordability of service risk (C_8); Agreement terms and type risk (C_9); Change in product design and operation quality risk (C_{10}). Five expert decision-makers (DMs), D_1 (Electrical Engineer), D_2 (Marketing Manager), D_3 (Economics analyst), D_4 (Statisticians) and D_5 (Production Manager), are engaged for selecting and ranking low risk locations among eight alternatives, namely: Surat (A_1), Gurguon (A_2), Bangalore (A_3), Ahmadabad (A_4), Aurangabad (A_5), Nasik (A_6), Kanpur (A_7) and Hyderabad (A_8), with respect to these ten risk attributes. Following steps of the above algorithm are utilized and the results are shown in the Tables below:

Step 1: $X = (A_i; i = 1, 2, \dots, 8)$ be a set of 8 alternative location for warehouse and $F = (C_j; j = 1, 2, 3, \dots, 10)$ be a set of risk criteria's.

Step 2: Using Sub-steps 2.1-2.2, calculate the step parameters to generate the fuzzy weight and degree of importance of criteria according to experts, shown in Table1-2 to generate the weights of evaluation criteria, shown in Table 2.

Table 1. Expert DMs five point Likert scale based on Rasch Model

Expert	Very Unimp- portant (1)	Unimportant (2)	General (3)	Important (4)	Very Impor- -tant(5)
DM _j					
DM ₁	-	(2,2,8)	(2,7,12)	(5,11,17)	(11,17,17)
DM ₂	(0,0,6)	(0,3,5,7)	(3,5,8,12,5)	(8,5,13,17,5)	(13,5,18,18)
DM ₃	-	(1,5,4,6,5)	(4,5,8,11,5)	(8,12,5,17,5)	(13,18,18)
DM ₄	(1,1,5)	(2,4,6)	(3,5,7,5,11,5)	(7,12,17)	(12,17,17)
DM ₅	-	(1,1,5)	(3,7,11)	(6,5,11,5,16,5)	(11,16,5,16,5)

Table 2. Importance of criteria according to five decision makers (DMj) and weight of criteria

Criteria	DM ₁	DM ₂	DM ₃	DM ₄	DM ₅	Average Wt W_C	Defuzzified $W_C = \text{BNP}_C$	Standardise $W_C = \text{SBNP}_C$
C_1	4	4	5	4	5	(8.9,14.1,17.2)	13.40	0.13180
C_2	4	5	5	5	5	(10.9,16.1,17.3)	14.76	0.14524
C_3	4	4	3	4	4	(6.3,11.1,15.9)	11.10	0.10918
C_4	5	4	3	4	3	(6.8,11.4,14.8)	11.00	0.10819
C_5	3	2	4	5	4	(5.7,10.3,14)	10.00	0.09836
C_6	3	2	3	2	3	(2.3,5.9,9.5)	5.90	0.05803
C_7	2	3	2	1	3	(2.2,4.4,8.6)	5.06	0.04983
C_8	4	5	4	5	5	(9.9,15,17.2)	14.03	0.13803
C_9	2	4	3	2	4	(4.3,6.9,10.7)	8.10	0.07967
C_{10}	4	2	3	4	3	(3.9,8.3,12.7)	8.30	0.08163

Table 3. Triangular Fuzzy Scale of the Linguistic Variables

Linguistic Variables	Triangular Fuzzy values	Defuzzified Value
Poor(P)	(0,0,3)	1
Fair(F)	(2,5,8)	5
Good(G)	(6,10,14)	10
Very Good(G)	(11,14,17)	14
Excellent(E)	(15,18,18)	17

Step 3: Eight alternative are evaluated with respect to ten risk criteria and all values assigned to alternative in respect to each criteria form a decision matrix by help of Table 4. Also positive and negative ideal solution values of all criteria are shown in Table 5.

Table 4. Ratings of criteria to alternatives with best f_i^* and worst f_i^- value

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀
A ₁	G	E	F	P	F	E	F	P	E	VG
A ₂	VG	F	VG	F	G	E	F	VG	E	P
A ₃	F	VG	E	F	G	F	G	P	VG	F
A ₄	E	G	F	E	G	G	VG	E	P	VG
A ₅	F	E	P	G	VG	F	G	P	VG	P
A ₆	P	E	VG	G	E	P	VG	F	F	G
A ₇	G	VG	G	F	P	E	P	G	F	E
A ₈	F	F	E	E	F	F	VG	P	F	VG
f_i^*	1	5	1	1	1	1	1	1	1	1
f_i^-	17	17	17	17	17	17	14	17	17	17

Step 4: Compute the values of S_i , R_i and Q_i and rank the respective alternatives using fuzzy VIKOR model, shown in Table 5.

Table 5. Calculating the values of S_i , R_i and Q_i and ranking of alternatives

Warehouse location (A_j)	Group) Utility S_j	Individual Regret R_j	Aggregating Index Q_j	Rank of alternatives ($v=0.5$)
1	0.490642	0.145246	0.645270	3
2	0.543367	0.112152	0.307156	5
3	0.510629	0.109180	0.193227	6
4	0.669986	0.138033	0.945935	1
5	0.467227	0.145246	0.593049	4
6	0.543361	0.145246	0.762848	2
7	0.508770	0.108934	0.185696	7
8	0.425512	0.109180	0.003393	8

5 Result Discussion

Using Step 7 of algorithm, $Q(A_4) - Q(A_6) = 0.945935 - 0.762848 = 0.183087 > 1/7$, so the first condition is satisfied. Also, alternative (A_4) also ranked best in terms of risks by corresponding values of S_j or Q_j considering $v = 0.5$ (for unbiased judgment of decision makers).

6 Conclusion and Future Areas of Research

The present study demonstrates the feasibility of applying Fuzzy Rasch method in VIKOR to analyze optimal low risk warehouse location selection. The propose hybrid method is to determine scores for all optimal locations minimizing the cost over an extended time period and the one with the highest score is finally chosen for implementation. In future the problem in this paper can be solved by Trapezoidal interval type-2 fuzzy ANP-PROMETHEE II or ELECTRA III and can also be applied in medical diagnosis, Pattern recognition and inventory management along with other MCDM problems.

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