Preference Selection Index Approach as MADM Method for Ranking of FMS Flexibility

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Abstract The idea of this study is to find the impact of FMS flexibilities because it is one of the key factors of the performance analysis of manufacturing system. "Preference selection index" (PSI) as a decision-making technique is used to detect the best flexibility from among flexibilities without deciding the weight of the attributes. PSI is authenticated in this work by differentiating the outcome of this method with the available results of different MADM approaches like AHP, TOPSIS, modified TOPSIS, improved PROMETHEE and VIKOR. The result of PSI approach shows that the topmost flexibility is production flexibility whenever related to the production with the new part configuration in FMS. This investigation research has accomplished that the PSI method is suitable for the selections of alternatives.

Keywords PSI · FMS · Flexibility · MADM

1 Introduction

Manufacturing companies are focusing on flexible manufacturing system (FMS) to improve the competitive advantage, inflexible customer demands, reduce direct labor cost, save indirect labor cost and enhance productivity as increased in customer service and on-time delivery. Stecke [1] defined that "FMS consists innumerable programmable and computerized machine tools connected by an automatic material handling system like robots and automatic guided vehicles (AGVs) and automatic

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storage and retrieval system (AS/RS) that can process simultaneously medium-sized volumes of the different parts". Rao [2] presented combined MADM methods like TOPSIS and AHP for ranking of FMSs. Raj, Shankar [3] applied AHP methodology for the ranking of manufacturing system. Jain and Raj [4] stated that "flexibility is one of the critical dimensions of enhancing the competitiveness of organizations". Jain and Raj [5] analyzed that "flexibility in manufacturing has been identified as one of the key factors to improve the performance of FMS". Jain and Raj [6] also discussed that flexibility is a significant factor of FMS productivity. Jain and Raj [4]used AHP, TOPSIS and improved PROMETHEE MADM methods for FMS flexibilities by different decision-making method and accomplished that "production flexibility is the topmost flexibility in FMS". VIKOR modified TOPSIS for the flexibility evaluations (Jain and Raj [7, 8]). Jain and Soni [9], Jain and Ajmera [10] discussed the performance factor by fuzzy TISM, AHP, CMBA and ELECTRE methodology.

In this research, fifteen flexibilities and variables from literature are considered as fifteen flexibilities (machine flexibility, routing flexibility, process flexibility, product flexibility, volume flexibility, material handling flexibility, operation flexibility, expansion flexibility, production flexibility, program flexibility, market flexibility, response flexibility, product mix flexibility, size flexibility and range flexibility) and fifteen variables (ability to manufacture a variety of products, capacity to handle new products, flexibility in production, flexible fixturing, combination of operation, automation, use of automated material handling devices, increase machine utilization, use of the reconfigurable machine tool, manufacturing lead time and setup time reduction, speed of response, reduced WIP inventories, reduction in material flow, quality consciousness and reduction in scrap) which effect the flexibility of FMS [4, 7, 8, 11–16].

The main concern of this research is to execute a novel approach as preference selection index (PSI) for ranking of flexibility based on variables which effect the flexibility of FMS. The PSI method suggests the effective alternative among the different alternatives without considering any subjective or relative importance between attributes [17]. In this paper, an overview of preference selection index approach is under in Sect. 2. In Sect. 3, analysis of ranking of flexibilities by preference selection index approach is discussed. Discussion and conclusion are discussed in Sect. 4.

2 PSI Methodology

PSI methodology was proposed by Maniya and Bhatt [18] as a MADM method. In this approach, relative importance between attributes is not necessary. Even, there is no requirement of defining the weights of attributes to solve the problems. In the previous studies, a number of MADM techniques are discussed as "graph theory and matrix approach (GTMA)", "analytic hierarchy process (AHP)", "analytic network process (ANP)", "technique for order preferences by similarity to ideal solution (TOPSIS)", "modified TOPSIS", "improved preference ranking organization method for enrichment evaluation method (PROMETHEE)", "compromise ranking method (VIKOR)", etc. These techniques look bit complex when numbers of variables are more in the problem [18]. While in the PSI method, calculations are very simple and results are found with minimum time as compared to other methods, and no weights of attributes are necessary for the calculations. According to Attri and Grover [19], it may be applied to any number of attributes.

PSI methods are used in different field to found the best choice. The literature has been reviewed from the perspective of this methodology.

Jain [20] analyzed the FMS performance factors by MOORA and PSI. Chauhan and Singh [21] applied preference selection index (PSI) methodology to find the optimal design parameters inside the duct. Singh and Patnaik [22] applied PSI for the ranking of the friction materials. Attri and Dev [23] used for selection of cutting fluids. Almomani and Aladeemy [24] determined the best setup technique based on AHP, TOPSIS and PSI methods. Maniya and Bhatt [25] applied for electrical energy equipment. Khorshidi and Hassani [26] did comparative analysis for selection of materials. Maniya and Bhatt [27] applied for the layout design. Vahdani and Zandieh [28] used for alternative fuel for buses. Maniya and Bhatt [17] solved for the FMS selection. Sawant and Mohite [29] used for automated guided vehicle selection. Joseph and Sridharan [30] applied PSI method in FMS for the ranking of scheduling rules. Maniya and Bhatt [18] used for the materials.

The following are the steps involved in the overview of the PSI approach [18–20]:

Step 1: To define the objective

Firstly, find out all alternatives, i.e., flexibilities, and there selection variables related to the application.

Step 2: To construct the decision matrix (D_{MXN})

After defining the objective, construct the decision matrix, i.e., the package of all information related to each alternative and attributes. In the decision matrix, where M is the "alternatives" which shows row and N is the "attributes" which shows column, which is expressed as the A_i alternative, i.e., A_i (i = 1, 2, 3, …., M) and for attribute B_j (j = 1, 2, 3, …., N). If the data is not quantitative mean qualitative, then convert it into qualitative with the help of fuzzy sets. The decision matrix is shown by Eq. (1).

$$\mathrm{D}_{MXN} = \begin{matrix} \text{Attributes} \\ A_1 \\ A_2 \\ A_3 \\ - \\ - \\ A_M \end{matrix} \begin{bmatrix} B_1 & B_2 & B_3 & -- & B_N \\ d_{11} & d_{12} & d_{13} & -- & d_{1\mathrm{N}} \\ d_{21} & d_{22} & d_{23} & -- & d_{2\mathrm{N}} \\ d_{31} & d_{32} & d_{33} & -- & d_{3N} \\ - & - & - & -- & - \\ - & - & - & -- & - \\ d_{M1} & d_{M2} & d_{M3} & -- & d_{\mathrm{MN}} \end{bmatrix} \quad (1)$$

Chen and Hwang [31] indicated "an approach to solve more than ten alternatives and they proposed first converts linguistic terms into fuzzy numbers and then the fuzzy numbers into crisp scores" [4].

Step 3: To normalize the attribute data (N_{ij})
In this decision-making approach, attribute value should be dimensionless. In this part, normalization takes place. The obtained values called as normalized values in terms of binary form, i.e., 0 and 1. In PSI methodology, normalization is done as given below

$$N_{ij} = \frac{d_{ij}}{d_j^{\max}}; \quad \text{“(if } i\text{th attribute is beneficial)”} \tag{2}$$

$$N_{ij} = \frac{d_j^{\min}}{d_{ij}}; \quad \text{“(if } j\text{th attribute is non-beneficial)”} \tag{3}$$

Step 4: To determine the “mean value of normalized attribute” data (N_{mean})
It is determined as per equation:

$$N_{\text{mean}} = \frac{1}{N}\sum_{i=1}^{N} N_{ij}$$

(where N_{mean} is the mean value of normalized attribute data) (4)

Step 5: To reckon the “preference variation value” (Ω_j)
It is reckoned as per equation:

$$\Omega_j = \sum_{i=1}^{N} \left[N_{ij} - N_{\text{mean}}\right]^2 \tag{5}$$

Step 6: To evaluate the deviation in “preference value” (Φ_j)
It is evaluated as per equation:

$$\Phi_j = \left[1 - \Omega_j\right] \tag{6}$$

Step 7: To obtain the “overall preference value” (Ψ_j)
It is obtained as per equation:

$$\Psi_j = \frac{\Phi_j}{\sum_{j=1}^{N} \Phi_j} \tag{7}$$

There is one condition to check, i.e., the “overall preference value” should be one and shown in Eq. 8.

$$\sum_{j=1}^{N} \Psi_j = 1 \tag{8}$$

Step 8: To quantify the "preference selection index" (PSI_i)
Now, it is quantified as per equation:

$$PSI_i = \sum_{j=1}^{N} \left(d_{ij} \times \Psi_j \right) \tag{9}$$

Step 9: To rank the alternatives
Each alternative is ranked either "ascending or descending" order according to PSI values. Highest PSI value alternative is ranked one, i.e., best alternative, and rest is so on.

3 Ranking of Flexibility by PSI

In this part, PSI methodology is applied for the ranking of FMS flexibility as given below.

Step 1: As per the objective, rank the flexibilities of FMS, fifteen flexibilities as alternatives and fifteen attributes are taken to evaluate the flexibilities.
Step 2: The values of attribute are in qualitative. So, fuzzy sets are applied to transform the linguistic data into crisp value, and it is shown as a decision matrix in Table 1.
Step 3: The normalization of attribute data is done as per Eq. 2.
Step 4: The "normalized mean value of each attribute" is determined by Eq. 4. It is depicted in Table 2.
Step 5: Each attributes' preference variation value is reckoned by Eq. 5. It is depicted in Table 3.
Step 6: The preference value deviation is evaluated by using Eq. 6. It is depicted in Table 4.
Step 7: The overall preference value is calculated by using Eq. 7. It is depicted in Table 5.
Step 8: By using Eq. 8, quantification of each alternative as the preference selection index (PSI_i) is depicted in Table 6.
Step 9: Now, alternatives are sorted as per preference selection index in descending order and shown in Table 6. From Table 6, according to PSI values production flexibility (9) is the top one rank.

4 Discussion and Conclusion

This PSI methodology is easy to understand in comparison with other methods. There is no requirement of weights of attributes because it uses the concept of statistics.

Table 1 Quantitative data for decision matrix

Alternatives (flexibilities)	Attributes														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.865	0.665	0.665	0.5	0.59	0.5	0.41	0.59	0.665	0.665	0.59	0.335	0.255	0.5	0.41
2	0.41	0.41	0.665	0.5	0.255	0.5	0.59	0.59	0.41	0.41	0.665	0.59	0.5	0.41	0.5
3	0.665	0.5	0.59	0.59	0.5	0.5	0.41	0.59	0.5	0.5	0.59	0.5	0.5	0.41	0.5
4	0.745	0.865	0.665	0.59	0.41	0.5	0.41	0.59	0.59	0.5	0.665	0.41	0.41	0.5	0.41
5	0.41	0.41	0.41	0.5	0.5	0.59	0.59	0.5	0.5	0.665	0.5	0.41	0.41	0.41	0.41
6	0.255	0.255	0.41	0.41	0.5	0.59	0.745	0.41	0.41	0.59	0.59	0.5	0.41	0.335	0.255
7	0.335	0.255	0.41	0.5	0.41	0.5	0.41	0.41	0.59	0.5	0.41	0.335	0.335	0.255	0.255
8	0.41	0.335	0.665	0.5	0.5	0.41	0.5	0.665	0.745	0.745	0.5	0.335	0.255	0.41	0.255
9	0.665	0.59	0.59	0.59	0.5	0.665	0.59	0.665	0.865	0.41	0.41	0.255	0.335	0.5	0.135
10	0.255	0.255	0.335	0.255	0.135	0.5	0.59	0.335	0.41	0.335	0.59	0.255	0.255	0.135	0.135
11	0.5	0.59	0.5	0.335	0.255	0.665	0.135	0.255	0.59	0.255	0.5	0.255	0.135	0.5	0.135
12	0.5	0.59	0.665	0.59	0.335	0.745	0.59	0.41	0.5	0.335	0.5	0.255	0.41	0.665	0.5
13	0.59	0.5	0.665	0.5	0.5	0.59	0.5	0.5	0.5	0.59	0.5	0.59	0.41	0.5	0.5
14	0.665	0.59	0.5	0.5	0.5	0.5	0.59	0.5	0.59	0.665	0.5	0.41	0.335	0.335	0.255
15	0.5	0.5	0.59	0.5	0.41	0.5	0.59	0.41	0.5	0.5	0.59	0.335	0.255	0.255	0.135

Table 2 Mean value of normalized data

N_{mean}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0.599	0.563	0.835	0.832	0.712	0.739	0.685	0.744	0.645	0.686	0.812	0.652	0.695	0.614	0.639

Table 3 Preference variation value

Ω_j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0.601	0.553	0.438	0.363	0.623	0.196	0.506	0.466	0.304	0.517	0.197	0.546	0.584	0.544	1.231

Table 4 Deviation in preference value

Φ_j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0.399	0.447	0.562	0.637	0.377	0.804	0.494	0.534	0.696	0.483	0.803	0.454	0.416	0.456	−0.231

Table 5 Overall preference value

Ψ_j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0.054	0.061	0.077	0.087	0.051	0.110	0.067	0.073	0.095	0.066	0.110	0.062	0.057	0.062	−0.031

Table 6 Preference selection index

PSI_i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0.563	0.506	0.528	0.571	0.496	0.476	0.424	0.517	0.571	0.363	0.422	0.523	0.534	0.522	0.484
Ranking	3	9	5	2	10	12	13	8	1	15	14	6	4	7	11

Secondly, no extra parameters are required in the calculation. The "computational time" of the PSI method in comparison with other MADM methods is less.

The main aim of this work is to concentrate on the ordering of fifteen FMS flexibility. In this study, ranking of flexibilities is found by a PSI approach, i.e., MADM method.

Jain and Raj [4] determined the ordering of flexibilities in flexible manufacturing system formed by approaches as AHP methodology, TOPSIS approach and improved PROMETHEE method are 9-4-1-12-13-3-14-5-8-2-15-6-11-7-10. As per ordering, top ranking is the production flexibility, i.e., no. 9, and last is program flexibility, i.e., no. 10, in flexible manufacturing system. By PSI method, got the ranking is 9-4-1-13-3-12-14-8-2-5-15-6-7-11-10. Ranking of flexibilities by different MADM is shown in Fig. 1.

To check the inconsistency with other MADM method correlation is found out by Spearman's rank among the PSI approach and the other methods. The correlation coefficient of Spearman's rank among the PSI approach and the other is shown in Fig. 2.

Finally concluded that PSI methodology can be used productively by the researcher or industrial persons for finding in different areas such as "material selection, product and process design, plant facility location, plant facility layout and material handling system selection".

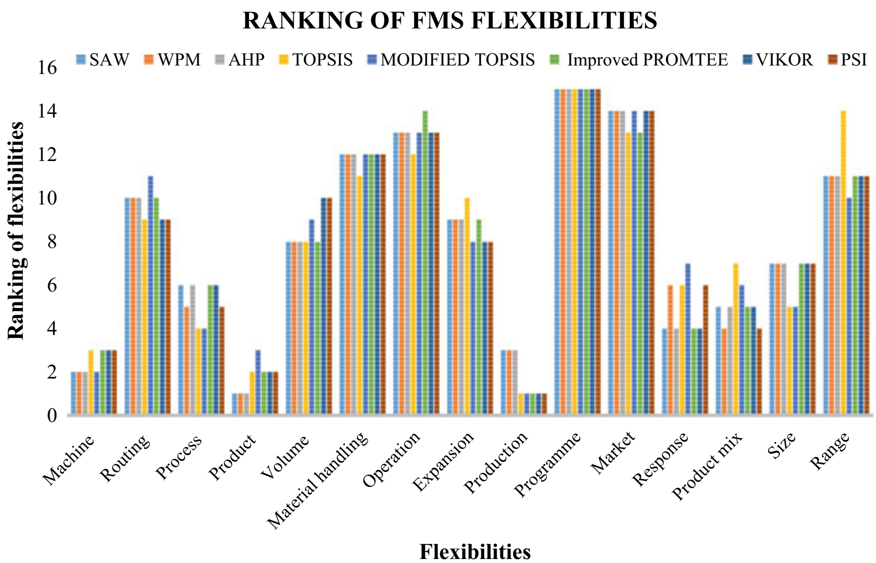

Fig. 1 Ranking of flexibilities

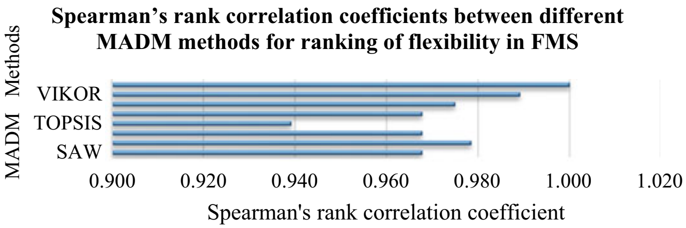

Fig. 2 Spearman’s rank correlation coefficients between different MADM methods for ranking of flexibility in FMS

References

1. Stecke KE (1983) Formulation and solution of nonlinear integer production planning problems for flexible manufacturing systems. Manage Sci 29(3):273–288
2. Rao RV (2008) Evaluating flexible manufacturing systems using a combined multiple attribute decision making method. Int J Prod Res 46(7):1975–1989
3. Raj T et al (2008) An AHP approach for the selection of Advanced Manufacturing System: a case study. Int J Manuf Res 3(4):471–498
4. Jain V, Raj T (2013a) Ranking of flexibility in flexible manufacturing system by using a combined multiple attribute decision making method. Global J Flexible Syst Manag 14(3):125–141
5. Jain V, Raj T (2016) Modeling and analysis of FMS performance variables by ISM, SEM and GTMA approach. Int J Prod Econ 171(1):84–96
6. Jain V, Raj T (2014a) Modelling and analysis of FMS productivity variables by ISM, SEM and GTMA approach. Front Mech Eng 9(3):218–232
7. Jain V, Raj T (2014b) Evaluation of flexibility in FMS by VIKOR methodology. Int J Ind Syst Eng 18(4):483–498
8. Jain V, Raj T (2015a) A hybrid approach using ISM and modified TOPSIS for the evaluation of flexibility in FMS. Int J Ind Syst Eng 19(3):389–406
9. Jain V, Soni VK (2019) Modeling and analysis of FMS performance variables by fuzzy TISM. J Model Manag 14(1):2–30
10. Jain V, Ajmera P (2019a) Evaluation of performance factors of FMS by combined decision making methods as AHP, CMBA and ELECTRE methodology. Manag Sci Lett 9(4):519–534
11. Jain V, Raj T (2015b) Modeling and analysis of FMS flexibility factors by TISM and fuzzy MICMAC. Int J Syst Assur Eng Manag 6(3):350–371
12. Jain V, Raj T (2013b) Evaluating the variables affecting flexibility in FMS by exploratory and confirmatory factor analysis. Global J Flexible Syst Manag 14(4):181–193
13. Jain V, Raj T (2013c) Evaluation of flexibility in FMS using SAW and WPM. Decision Sci Lett 2(4):223–230
14. Jain V, Raj T (2015c) Evaluating the intensity of variables affecting flexibility in FMS by graph theory and matrix approach. Int J Ind Syst Eng 19(2):137–154
15. Jain V, Raj T (2018) Identification of performance variables which affect the FMS: a state-of-the-art review. Int J Process Manag Benchmark 8(4):470–489
16. Jain V, Ajmera P (2019b) Application of MADM methods as MOORA and WEDBA for ranking of FMS flexibility. Int J Data Netw Sci 3(2):119–136
17. Maniya K, Bhatt M (2011a) The selection of flexible manufacturing system using preference selection index method. Int J Ind Syst Eng 9(3):330–349
18. Maniya K, Bhatt M (2010) A selection of material using a novel type decision-making method: preference selection index method. Mater Des 31(4):1785–1789

19. Attri R, Grover S (2015) Application of preference selection index method for decision making over the design stage of production system life cycle. J King Saud Univ-Eng Sci 27(2):207–216
20. Jain V (2018) Application of combined MADM methods as MOORA and PSI for ranking of FMS performance factors. Benchmark Int J 25(6):1903–1920
21. Chauhan R et al (2016) Optimization of parameters in solar thermal collector provided with impinging air jets based upon preference selection index method. Renew Energy 99:118–126
22. Singh T et al (2015) Optimization of tribo-performance of brake friction materials: effect of nano filler. Wear 324:10–16
23. Attri R et al (2014) Selection of cutting-fluids using a novel, decision-making method: preference selection index method. Int J Inf Decision Sci 6(4):393–410
24. Almomani MA et al (2013) A proposed approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques. Comput Ind Eng 66(2):461–469
25. Maniya K, Bhatt M (2013) A selection of optimal electrical energy equipment using integrated multi criteria decision making methodology. Int J Energy Optim Eng (IJEOE) 2(1):101–116
26. Khorshidi R, Hassani A (2013) Comparative analysis between TOPSIS and PSI methods of materials selection to achieve a desirable combination of strength and workability in Al/SiC composite. Mater Des 52:999–1010
27. Maniya K, Bhatt M (2011b) An alternative multiple attribute decision making methodology for solving optimal facility layout design selection problems. Comput Ind Eng 61(3):542–549
28. Vahdani B, Zandieh M, Tavakkoli-Moghaddam R (2011) Two novel FMCDM methods for alternative-fuel buses selection. Appl Math Model 35(3):1396–1412
29. Sawant V, Mohite s, Patil R (2011) A decision-making methodology for automated guided vehicle selection problem using a preference selection index method. In: Technology systems and management. Springer, pp 176–181
30. Joseph O, Sridharan R (2011) Ranking of scheduling rule combinations in a flexible manufacturing system using preference selection index method. Int J Adv Oper Manag 3(2):201–216
31. Chen SJ, Hwang CL (1992) Fuzzy multiple attribute decision making methods. In: Lecture notes in economics and mathematical systems. Springer Berlin, Heidelberg, pp 289–486