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ORIGINAL ARTICLE

Decision making over the production system life cycle: MOORA method

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Abstract Decisions in robust and flexible production systems are made in an environment often characterized by complexity, need for flexibility, and inclusion of a decision-maker's subjectivity. Typically in production system life cycle, decisions on the product design, facility location, facility layout, supplier, material, technology, and so forth has to be made in an efficient and timely manner. These decisions are more complex as the decision makers have to assess a wide range of alternatives based on a set of conflicting criteria. In this paper, application of multi-objective optimization on the basis of ratio analysis approach is explored to solve such type of decision making problems. Moreover performance of the reference point approach is also tested for the considered decision making problems.

Keywords MOORA · Ranking · Assessment · Decision · Production system · Life cycle

1 Introduction

As in product life cycle, the product goes through several distinct stages: introduction, growth, maturity, decline and death. The marketing decisions at each stage of the product life cycle are typical. The same concept is extended to a production system as a whole. In the introduction stage of production, product and its design is selected. The manufacture has to provide facilities to manufacture it. All these decisions are major strategic decisions, taken by the promoters of an industry. Immediately thereafter, the production system becomes steady as most on-going organizations are. Here the decisions are short term tactical decisions. Here the system is influenced slightly by internal and external environmental changes. When there are radical changes in external environment, and the production system finds it difficult to adopt those changes, the system comes to end (Attri and Grover 2012; Chunawalla and Patel 2009).

The life cycle of production system shows the progress of production system from the inception to the termination of system. Bellgran and Säfsten (2010) and Attri and Grover (2013a) have discussed that the main activities within the production system are often described based on the products life-cycle such as (i) market activity places demands on the product delivered from the production system, engineering activity controls the product development; (ii) production activity creates the product in the production system; (iii) distribution activity makes sure that the product is delivered under the right conditions to the customer; (iv) service activity targets at eliminating and inhibiting defects which might appear in the product; and (v) recycling activity objects at saving resources and handles worn-out material. Figure 1 shows the key activities to be performed in different stages of a production system life cycle.

In each stage of the production system life-cycle, certain decisions have to be taken. For example, in the first stage i.e. initiation of the system, decision on product is to be taken. In design stage, several strategic decisions such as selection of product design, material, facility location, facility layout, process and technology has to be made. While in operation stage, decision on machine selection, manpower selection, vendor selection, job design etc. is to

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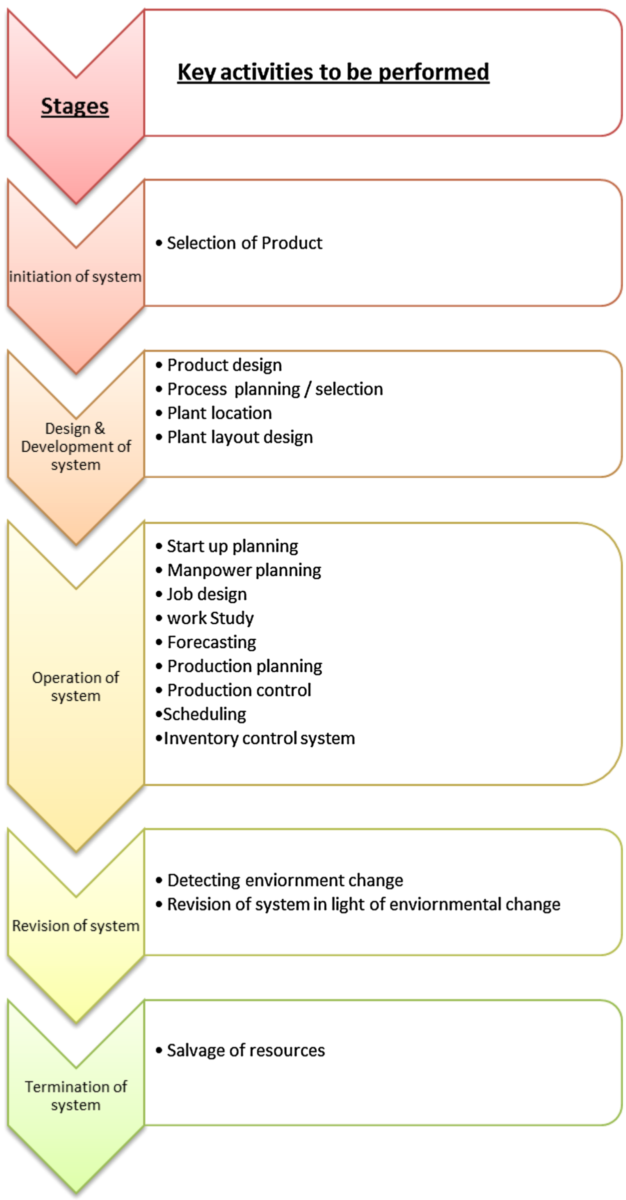

Fig. 1 Production system life cycle (Attri and Grover 2012)

be made. In revision stage, there may be decision on the change of technology in the light of the environment change. In last stage, decision on the termination of the system is to be taken.

Yamada et al. (2010) have predicted the product quality on the basis of software process data. Singh et al. (2011) have applied the graph theoretic approach (GTA) to judge the best manufacturing process among various manufacturing processes for manufacturing any product. Attri and Grover (2013b) have applied VIKOR method (compromise ranking method) for decision making over the design stage of the production system life cycle. Rao et al. (2010) have applied stochastic programming in graded manpower systems for the development of optimal manpower recruitment. Although, a number of multi-attribute decision making (MADM) techniques are available in literature to assist the decision makers in making good judgments. This paper endeavours to explore the applicability of a novel MADM method, i.e. multi-objective optimization on the basis of ratio analysis (MOORA) method to deal with the decision making problems in the production system life cycle.

2 MOORA approach

Multi-objective optimization on the basis of ratio analysis (MOORA) is also known as multi-criteria or multi-attribute optimization. It is defined as the process of simultaneously optimizing two or more conflicting attributes subject to some constraints (Chakraborty 2011; Karande and Chakraborty 2012). Multi-criteria problem can be found in different stages of production system life cycle such as product design, process design, material selection, machine tool or cutting tool selection, material handling system selection, advanced manufacturing system selection. This approach was introduced by Brauers (2004).

This approach starts with a matrix consisting of performance measures of different alternatives with respect to various criteria.

$$X = \begin{Bmatrix} x_{11} & x_{12} & \ldots & \ldots & x_{1n} \\ x_{21} & x_{21} & \ldots & \ldots & x_{2n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_{m1} & x_{m2} & \ldots & \ldots & x_{mn} \end{Bmatrix} \quad (1)$$

where x_{ij} is the performance measure of the ith alternative on the jth attribute, m is the number of alternatives and n is the number of the attributes.

MOORA approach consists of two parts namely ratio system approach, the reference point approach.

2.1 Ratio system approach

In the ratio system approach, the initial data in the decision matrix is normalized. The reason behind the normalization is to make the decision matrix dimensionless. This makes all the elements of the decision matrix comparable. For normalization, different procedures are suggested by the authors Karande and Chakraborty (2012) and Brauers et al. (2010).

According to Karande and Chakraborty (2012), normalization can be done by comparing the performance of an alternative on a criterion to a denominator which is a representative for all the alternatives concerning that criterion.

$$X_{ij}^{*} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \quad (2)$$

where X_{ij}^{*} is a dimensionless number in the [0, 1] interval, which represents the normalized performance of the ith alternative on the jth criterion. The elements of the matrix are normalized without considering the type of the attribute i.e. beneficial attribute or non-beneficial attribute. Beneficial attributes are those attributes whose higher values are required, while for non-beneficial attributes, lower values are required.

For optimization based on ratio system approach of MOORA method, normalized performances are added in case of beneficial attributes (maximization) and subtracted in case of non-beneficial attributes (minimization), which can be expressed by following expression:

$$y_i^{*} = \sum_{j=1}^{g} X_{ij}^{*} - \sum_{j=g+1}^{n} X_{ij}^{*} \quad (3)$$

where y_i^{*} is the assessment value of the ith alternative with respect to all the criteria, g is the number of criteria to be maximized, and $(n - g)$ is the number of the criteria to be minimized.

Furthermore the value of y_i^{*} can be positive or negative depending on the totals of beneficial and non-beneficial attributes in the matrix. The alternative with highest value of y_i^{*} would be the best alternative. An ordinal ranking of y_i^{*} shows the final preference.

In some cases, some attributes are more significant than others. In these cases attribute weight is taken into deliberation. The weights of the attribute can be determined by applying entropy method and analytical hierarchy process (AHP). When weights of the attributes are considered, Eq. (3) becomes as follows:

$$y_i^{*} = \sum_{j=1}^{g} w_i X_{ij}^{*} - \sum_{j=g+1}^{n} w_i X_{ij}^{*} \quad (4)$$

where w_i is the weight of the jth attribute.

2.2 Reference Point Approach

In the reference point theory a maximal objective reference point is deduced from the ratios found in Eq. (2). This approach is also known as realistic and non-subjective when the coordinates (r_i) selected for the reference point are realized in one of the candidate alternatives (Brauers et al. 2008).

The set of reference point series is obtained on the basis of the beneficial and non-beneficial attributes. It will consist of maximum value in case of beneficial attribute and minimum value in case of non-beneficial attribute. The deviation of a criterion value from the set reference point (r_i) is computed as:

$$r_i - X_{ij}^{*} \quad (5)$$

From the reference point approach of MOORA, best alternative is one which would possess the maximum values in all of its beneficial attributes and minimum values in its non-beneficial attributes. It is not possible all the times that a specific alternative having all of the maximum values in its beneficial attributes and minimum values in its non-beneficial attributes. In such cases, there will be deviation from the set of reference point series.

Karlin and Studden (1966); Brauers and Zavadskas (2006) have proposed following formula for optimization based on reference point approach:

$$P_i = \underset{(i)}{Min}\left\{ \underset{(j)}{Max} \quad |r_i - X_{ij}^{*}| \right\} \quad (6)$$

where P_i is the performance index.

The best alternative would be one which has the total minimum deviation from the set of reference point series. In other words, it will have the minimum value of P_i.

3 Illustrative examples

To demonstrate the applicability, accuracy and potentiality of the MOORA method in decision making over the different stages of production system life cycle, the following five problems are cited here.

3.1 Product design selection

This problem deals with the selection of the most appropriate product design for the power electronic device (Besharati et al. 2006). This product design selection problem consists of ten design alternatives and three performance attributes i.e. manufacturing cost (MC), junction temperature, and thermal cycles to failure, as shown in Table 1. Among these three attributes thermal cycles to failure is a beneficial attribute and MC, junction temperature are non-beneficial attribute.

The decision matrix for the product design selection problem is shown in Table 1. Applying Eq. (2), the normalized decision matrix is obtained, as shown in Table 2.

Rao (2007) solved the same product design selection problem using AHP approach. Rao (2007) determined the criteria weights as $W_{JT} = 0.1047$, $W_{TCF} = 0.2582$, and $W_{MC} = 0.6371$ using the same method. In the current problem same weights are used here for subsequent analysis. After this, normalized assessment values (y_i) of all the considered alternatives are computed using Eq. (4) as

Table 1 Qualitative data for example 1 (Besharati et al. 2006)

Design no.	JT	TCF	MC
1	126	22,000	85
2	105	38,000	99
3	138	14,000	65
4	140	13,000	60
5	147	10,600	52
6	116	27,000	88
7	112	32,000	92
8	132	17,000	75
9	122	23,500	85
10	135	15,000	62

JT junction temperature in °C, *TCF* thermal cycles to failure, *MC* manufacturing cost in $

Table 2 Normalized decision matrix for example 1

Design no.	JT	TCF	MC
1	0.0990	0.1037	0.1114
2	0.0825	0.1792	0.1298
3	0.1084	0.0660	0.0852
4	0.1100	0.0613	0.0786
5	0.1155	0.0500	0.0682
6	0.0911	0.1273	0.1153
7	0.0880	0.1509	0.1206
8	0.1037	0.0802	0.0983
9	0.0958	0.1108	0.1114
10	0.1060	0.0707	0.0813

Table 3 Ranking of the alternative for example 1

Design no.	P_i	y_i	Rank
1	0.0276	−0.0546	10
2	0.0393	−0.0450	3
3	0.0293	−0.0486	6
4	0.0305	−0.0458	4
5	0.0334	−0.0426	1
6	0.0301	−0.0502	7
7	0.0334	−0.0471	5
8	0.0256	−0.0528	9
9	0.0276	−0.0524	8
10	0.0280	−0.0446	2

shown in Table 3. Moreover, Table 3 also exhibits the value of performance indices.

This MOORA method based analysis gives a comparative ranking of 5–10–2–4–7–3–6–9–8–1 when arranged according to the descending order of their assessment values. For this problem, product design 5 is the best choice among the considered ten product designs for the given power electronic device. Besharati et al. (2006) obtained the ranking for the product design alternatives as 5–10–4–3–7–6–2–8–9–1, while Rao (2007) obtained ranking 5–4–10–2–3–7–6–8–9–1. Here, alternative five is also observed as the best choice in both cases. In all the cases, the worst choice is product design 1. The ranking performance of MOORA method with respect to those derived by Besharati et al. (2006) and Rao (2007) are exhibited in Fig. 2.

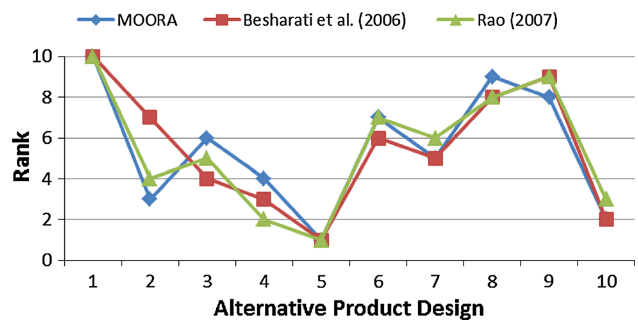

Fig. 2 Comparative ranking for example 1

Table 4 Qualitative data for example 2 (Rao and Singh 2012)

Layout alternatives	IEFD	AAG	MQF	AFF	COC
1	102	3,000	200	94	Very low (0.1364)
2	84	1,800	140	82	High (0.6667)
3	123	2,200	230	56	Average (0.5)
4	224	2,500	180	98	Low (0.3333)

IEFD interaction with existing facility distance in metres, *AAG* area available for each assembly group in m^2, *MQF* material quantity flow in kg/h, *AFF* accessibility for fire fighting in %, *COC* comfort of crew

Table 5 Normalized decision matrix for example 2

Layout alternatives	IEFD	AAG	MQF	AFF	COC
1	0.1914	0.3158	0.2667	0.2848	0.0834
2	0.1576	0.1895	0.1867	0.2485	0.4074
3	0.2308	0.2316	0.3067	0.1697	0.3055
4	0.4203	0.2632	0.2400	0.2970	0.2037

3.2 Facility layout design selection

Rao and Singh (2012) applied weighted euclidean distance based approach (WEDBA) to select plant layout design for a chemical packaging industry situated in the western part of India. This problem consists of four alternative plant layout design and five attributes i.e. interaction with existing facility distance, area available for each assembly group, material quantity flow, accessibility for fire fighting and comfort of crew, as shown in Table 4. Among these

Table 6 Ranking of the alternative for example 2

Layout alternatives	P_i	y_i	Rank
1	0.1110	0.0984	4
2	0.0129	0.1892	1
3	0.0349	0.1372	2
4	0.0698	0.0769	3

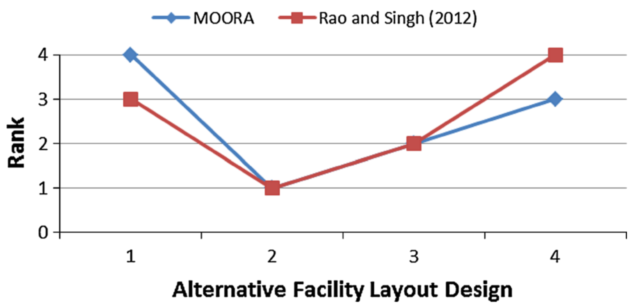

Fig. 3 Comparative ranking for example 2

Table 7 Qualitative data for example 3 (Kulak and Kahraman 2005)

Alternative FMS	ADM	Q	E	C	A	X
1	0.665	0.955	0.865	0.955	0.865	0.865
2	0.255	0.865	0.745	0.865	0.865	0.865
3	0.5	0.745	0.745	0.865	0.955	0.745
4	0.335	0.5	0.745	0.865	0.865	0.745

ADM annual depreciation and maintenance costs, *Q* quality of results, *E* ease of use, *C* competitiveness, *A* adaptability, *X* expandability

three attributes interaction with existing facility distance is a beneficial attribute and remaining ones are non-beneficial attributes.

Using Eq. (2), the quantitative data for the facility layout design selection problem are first normalized, as given in Table 5.

Rao and Singh (2012) determined the criteria weights as $W_{IEFD} = 0.2491$, $W_{AAG} = 0.0995$, $W_{MQF} = 0.1068$, $W_{AFF} = 0.2022$, $W_{COC} = 0.3423$ using AHP method which are subsequently used here for the MOORA method based analysis. Then, normalized assessment values (y_i) of all alternatives are computed using Eq. (4) as shown in Table 6.

Table 6 also exhibits the value of performance indices. A ranking of 2–3–4–1 is derived when the assessment values are sorted in ascending order. Rao and Singh (2012) derived a ranking of the considered alternatives as 2–3–1–4. In both the cases, first ranked facility layout exactly match. The ranking performance of MOORA method with respect to those derived by Rao and Singh (2012) is exhibited in Fig. 3.

Table 8 Normalized decision matrix for example 3

Alternative FMS	ADM	Q	E	C	A	X
1	0.3789	0.3116	0.2790	0.2690	0.2437	0.2686
2	0.1453	0.2822	0.2403	0.2437	0.2437	0.2686
3	0.2849	0.2431	0.2403	0.2437	0.2690	0.2314
4	0.1909	0.1631	0.2403	0.2437	0.2437	0.2314

Table 9 Ranking of the alternative for example 3

Alternative FMS	P_i	y_i	Rank
1	0.0978	0.0045	4
2	0.0055	0.0894	1
3	0.0584	0.0228	3
4	0.0278	0.0455	2

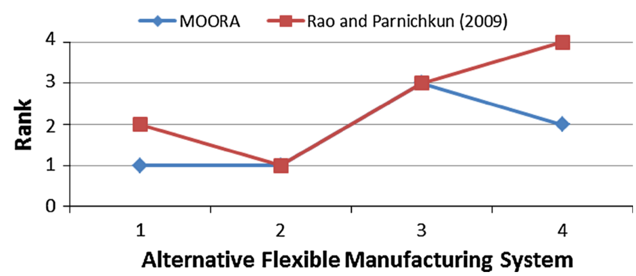

Fig. 4 Comparative ranking for example 3

3.3 Flexible manufacturing system selection

Kulak and Kahraman (2005) proposed axiomatic design (AD) principles for multiple attribute comparison of advanced manufacturing systems. This flexible manufacturing system selection problem consists of four alternative flexible manufacturing systems and six attributes. Decision matrix for the flexible manufacturing system (FMS) selection problem is shown in Table 7. The attributes considered are annual depreciation and maintenance costs), quality of results, ease of use, competitiveness, adaptability and expandability. In the current problem, annual depreciation and maintenance cost is the non-beneficial attribute and the remaining ones are the beneficial attributes.

On applying Eq. (2), the normalized decision matrix is obtained, as shown in Table 8.

Rao and Parnichkun (2009) solved the same problem using the combinatorial mathematics based method. Rao and Parnichkun (2009) determined the criteria weights as $W_{ADM} = 0.4188$, $W_Q = 0.1873$, $W_E = 0.0688$, $W_C = 0.1873$, $W_A = 0.0688$, $W_X = 0.0688$ using AHP method. The weights as derived by Rao and Parnichkun (2009) are used here for subsequent analysis. Values of normalized assessment (y_i) and performance indices (P_i) are shown in Table 9.

Table 10 Qualitative data for example 4 (Rao 2007)

Welding process	WQ	OF	SR	CR	AC	IP
SMAW	0.5	0.5	0.5	0.665	0.745	0.5
GTAW	0.745	0.665	0.745	0.5	0.5	0.665
GMAW	0.59	0.745	0.665	0.59	0.665	0.745

WQ weld quality, *OF* operator fatigue, *SR* skill required, *CR* cleaning required after welding, *AC* availability of consumables, *IP* initial preparation required

Table 11 Normalized decision matrix for example 4

Welding process	WQ	OF	SR	CR	AC	IP
SMAW	0.2725	0.2618	0.2618	0.3789	0.3901	0.2618
GTAW	0.4060	0.3482	0.3901	0.2849	0.2618	0.3482
GMAW	0.3215	0.3901	0.3482	0.3362	0.3482	0.3901

Table 12 Ranking of the alternative for example 4

Welding process	P_i	y_i	Rank
SMAW	0.0404	−0.0548	1
GTAW	0.0234	−0.0641	2
GMAW	0.0310	−0.0931	3

Table 13 Qualitative data for example 5 (Liu et al. 2000)

Supplier	P	Q	DP	D	SV
1	100	100	90	249	2
2	100	99.79	80	643	13
3	100	100	90	714	3
4	100	100	90	1,809	3
5	100	99.83	90	238	24
6	100	96.59	90	241	28
7	100	100	85	1,404	1
8	100	100	97	984	24
9	100	99.91	90	641	11
10	100	97.54	100	588	53
11	100	99.95	95	241	10
12	100	99.85	98	567	7
13	100	99.97	90	567	19
14	100	91.89	90	967	12
15	80	99.99	95	635	33
16	100	100	95	795	2
17	80	99.99	95	689	34
18	100	99.36	85	913	9

P price in $, *Q* quality in %, *DP* delivery performance in %, *D* distance in miles, *SV* supply variety

Table 14 Normalized decision matrix for example 5

Supplier	P	Q	DP	D	SV
1	0.0568	0.0560	0.0547	0.0193	0.0069
2	0.0568	0.0559	0.0486	0.0499	0.0451
3	0.0568	0.0560	0.0547	0.0554	0.0104
4	0.0568	0.0560	0.0547	0.1404	0.0104
5	0.0568	0.0559	0.0547	0.0185	0.0833
6	0.0568	0.0541	0.0547	0.0187	0.0972
7	0.0568	0.0560	0.0517	0.1090	0.0035
8	0.0568	0.0560	0.0590	0.0764	0.0833
9	0.0568	0.0560	0.0547	0.0497	0.0382
10	0.0568	0.0547	0.0608	0.0456	0.1840
11	0.0568	0.0560	0.0578	0.0187	0.0347
12	0.0568	0.0559	0.0596	0.0440	0.0243
13	0.0568	0.0560	0.0547	0.0440	0.0660
14	0.0568	0.0515	0.0547	0.0750	0.0417
15	0.0455	0.0560	0.0578	0.0493	0.1146
16	0.0568	0.0560	0.0578	0.0617	0.0069
17	0.0455	0.0560	0.0578	0.0535	0.1181
18	0.0568	0.0557	0.0517	0.0709	0.0313

A ranking of 2–4–3–1 is derived when the assessment values are sorted in ascending order. Rao and Parnichkun (2009) derived a ranking of the considered alternatives as 2–1–3–4. In both the cases, first ranked facility layout exactly match. The ranking performance of MOORA method with respect to those derived by Rao and Parnichkun (2009) is exhibited in Fig. 4.

3.4 Welding process selection

This example is related with the selection of a suitable arc welding process to join mild steel (0.2 % C) of 6 mm thickness (Rao 2007). This welding process selection problem consists of three alternate arc welding processes i.e. shielded metal arc welding, gas tungsten arc welding, and gas metal arc welding. The attributes considered are: weld quality, operator fatigue, skill required, cleaning required after welding, availability of consumables and initial preparation required. Among these attributes weld quality and availability of consumables are the beneficial attributes while the remaining ones are the non-beneficial attributes.

The decision matrix for the welding process selection problem is shown in Table 10. Applying Eq. (2), the normalized decision matrix is obtained, as shown in Table 11.

Rao (2007) determined the criteria weights as $W_{WQ} = 0.3534$, $W_{OF} = 0.2526$, $W_{SR} = 0.1669$, $W_{CR} = 0.1103$, $W_{AC} = 0.0695$, and $W_{IP} = 0.0473$ using AHP method.

Table 15 Ranking of the alternative for example 5

Supplier	P_i	y_i	Rank
1	0.0139	0.0331	12
2	0.0109	0.0332	11
3	0.0136	0.0318	14
4	0.0136	0.0281	18
5	0.0079	0.0391	5
6	0.0068	0.0393	4
7	0.0141	0.0282	17
8	0.0079	0.0377	6
9	0.0114	0.0342	10
10	0.0015	0.0468	1
11	0.0117	0.0361	8
12	0.0125	0.0346	9
13	0.0092	0.0367	7
14	0.0111	0.0312	16
15	0.0054	0.0426	3
16	0.0139	0.0321	13
17	0.0052	0.0427	2
18	0.0120	0.0318	15

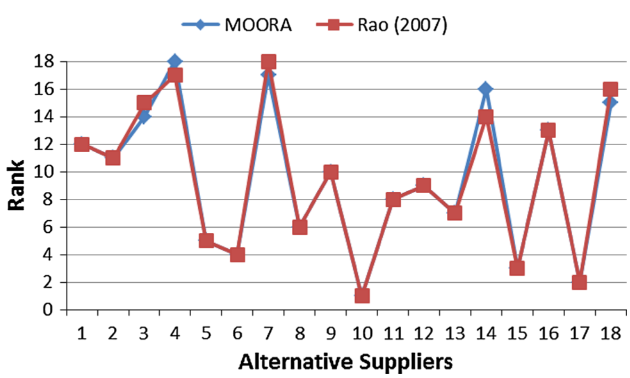

Fig. 5 Comparative ranking for example 5

Same weights are used here for subsequent analysis. Normalized assessment values (y_i) and performance indices of the considered alternatives are shown in Table 12.

From the Table 12, a ranking of SMAW–GTAW–GMAW is derived. Rao (2007) obtained ranking of SMAW–GTAW–GMAW. The result exactly matches with that of the Rao (2007).

3.5 Supplier selection

This example deals with the supplier performance evaluation using data envelopment analysis (DEA) in an agricultural and construction equipment manufacturing organization (Liu et al. 2000). Liu et al. (2000) considered five criteria, i.e. price, quality, delivery performance, distance and supply variety while evaluating the performance of 18 alternative suppliers engaged in supplying hydraulic valves. Among the five criteria considered in the present problem, quality, delivery performance and supply variety are the beneficial attributes, and price and distance are the non-beneficial attributes. Decision matrix of the problem consisting of 18 suppliers and five evaluation criteria, is shown in Table 13.

The corresponding normalized decision matrix is given in Table 14.

Rao (2007) solved the same problem using TOPSIS method. Rao (2007) determined the criteria weights as $W_P = 0.1361, W_Q = 0.4829, W_{DP} = 0.2591, W_D = 0.0438$, and $W_{SV} = 0.0782$ using AHP method. Same weights are used here for subsequent analysis. Table 15 shows the normalized assessment values (y_i) and performance indices.

From the Table 15, a ranking of 10–17–15–6–5–8–13–11–12–9–2–1–16–3–18–14–7–4 is derived. Rao (2007) obtained ranking of 10–17–15–6–5–8–13–11–12–9–2–1–16–14–3–18–4–7. The first ranking exactly matches with that of the Rao (2007). The ranking performance of MOORA method with respect to those derived by Rao (2007) is exhibited in Fig. 5.

Table 16 shows the comparative performance of MOORA method with other MADM methods on the basis of their computational time, simplicity and calculation involved (Chakraborty 2011; Ginevičius and Podvezko 2008).

It is observed from the Table 16 that MOORA method involves less mathematical calculations as it is based on the simple ratio analysis (as explained in Sect. 2). So, MOORA method is very simple to understand and easy to apply, when it is compared to other MADM techniques. Chakraborty (2011) have listed the following advantages of MOORA over the other MADM methods:

- Less computational time required for performing mathematical calculations.
- No extra parameters are required in this approach such as ν in VIKOR method and ξ in GRA method.

These advantages of MOORA method has made it more favourable to the decision making problems. Moreover, Brauers and Zavadskas (2009) have identified the MOORA method as the robust method which provides the stable result as compared to other MADM methods.

4 Conclusion

In the production system life cycle, numerous decisions are to be taken in each stage. These decisions are more complex as the decision makers has to assess a wide range of alternatives based on a set of conflicting criteria. In view of this, a novel multiple decision making MOORA method is suggested in this paper for decision making in different

Table 16 Comparative performance of MOORA method with other MADM methods

MADM method	Computational time	Simplicity	Mathematical calculations required
MOORA (multi-objective optimization on the basis of ratio analysis)	Very less	Very simple	Minimum
AHP (analytic hierarchy process)	Very high	Very critical	Maximum
ANP (analytic network process)	Moderate	Moderately critical	Moderate
GRA (grey relational analysis)	Very high	Very critical	Maximum
VIKOR (compromise ranking method)	Less	Simple	Moderate
GTA (graph theoretic approach)	Very high	Very critical	Maximum
ELECTRE (elimination and et choice translating reality)	High	Moderately critical	Moderate
DEA (data envelopment analysis)	Very high	Very critical	Maximum
TOPSIS (technique for order preference by similarity to ideal solution)	Moderate	Moderately critical	Moderate
PROMETHEE (preference ranking organization method for enrichment evaluation)	High	Moderately critical	Moderate

stages of production system life cycle. For the demonstration of proposed method, five examples have been cited from the literature. In all the cases, it is observed that best alternative exactly matches with those derived by the past researchers. MOORA method can consider all the attributes along with their relative importance which results in better evaluation of alternatives. MOORA method is very simple to comprehend and easy to apply. The proposed method is a general method and can consider any number of quantitative and qualitative attributes simultaneously and offers a more objective and simple decision making approach. Furthermore, this method can be extended to any type of selection problems.

MOORA method can be effectively used by the management or decision makers to make accurate decisions in different areas of manufacturing environment such as product design, material, manufacturing system, facility location, facility layout, material, and technology, supplier in an efficient and timely manner. However, this method is based on manual mathematical calculations, which has necessitated the development of computer program, which in turn will reduce the computational time. In future, computer program may be developed by using C++ language.

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