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Application of multi-attribute decision-making methods for the selection of conveyor

S. B. Fulzele[1] · S. B. Khatke[1] · S. J. Kadam[1] · A. G. Kamble[1]

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Abstract
In the present time of innovation, conveyor is an exceptionally indispensable part and has huge significance for material handling in various process and manufacturing industries. It is made with precisions, and the expenses are relatively high and should work with better productivity. The selection of the best conveyor is a crucial task, and the designers need to recognize different attributes that will influence the functionalities of the conveyor system to limit bottlenecks in the system. Researchers have worked on strategies for finding the best optimum solution for various selection problems, but conveyor selection using selected methods is not reported. Therefore, the present work aims to the selection process of the best option for conveyor by using four selected decision-making methods such as analytical hierarchy process, technique of order preference by similarity to ideal solution, compromise ranking method and Deng's similarity-based method. The selection is done among four alternatives based on six attributes, viz. fixed cost each hour, variable cost each hour, conveyor speed, product width, product weight and flexibility. The analytical hierarchy process is used to determine weights of the attributes based on relative importance of each attribute. It is observed that A3 conveyor is best suitable conveyor. Hence, the proposed strategies help manufacturers to examine and choose the best conveyor.

Keywords Conveyor selection · Analytical hierarchy process · Technique of order preference by similarity to ideal solution · Compromise ranking method · Deng's similarity-based method, etc.

1 Introduction

Nowadays, the material handling conveyors are the backbone of many industries. A conveyor system is a mechanical device that moves items from one location to another. It is utilized in a variety of processing and manufacturing industries. The different conveyor systems have been established for conveying materials or products from one location to another, depending on the speed of handling, nature, amount, size and weight of commodities to be carried. The determination of the best option of conveyor for developing a dependable and efficient conveyor system will save money and increase production and lowering the risk of workers operating it. The appropriate planning of material handling is also required for minimizing the delivery time, and it leads to lower overall expenses of the manufacturing and improves customer service and reduces inventory cost. In India, 80% of material handling is done by conveyors in most of the industries and the worldwide transport framework market size is projected to arrive at USD 10.6 billion by 2025, from an expected worth of USD 8.8 billion in 2021. Thus, various processing and manufacturing plants are improving the performance of conveyor systems. Therefore, best conveyor must be chosen to reduce impact and wear of the conveyor and thereby increase durability and strength.

The proper selection of material handling equipment is a critical issue for the efficiency and productivity of industrial organizations in the global market. Also, it is a time-consuming and expensive process (Goswami and Behera 2021**)**. In comparison with other modes of transportation, belt conveyors have traditionally been an efficient technique of transporting huge amounts of material. Speed control is supposed to reduce belt conveyor energy consumption; however, the issue is the management of the

✉ S. B. Fulzele
sbfulzele@mitaoe.ac.in

[1] School of Mechanical and Civil Engineering, MIT Academy of Engineering, Alandi, Pune, Maharashtra 412105, India

conveyor's dynamic behaviour and speed control, both of which are critical which can result in high energy consumption and poor performance (Mhlongo et al. 2020). There are many important parameters which play a vital role in meticulous selection of a conveyor system. It is important to know how the conveyor system will be used prior to the setup; hence, some individual areas that are helpful to consider are the required conveyor operations such as conveyor capacity, material to be conveyed, material characteristics and many more design parameters (Chudasama et al. 2021). The industries are dealing with difficult issues related to conveyor selection; therefore, it appears that they are reluctant to apply performance-based rankings for manufacturers. When it comes to material handling, there are always trade-offs between quality and cost. As a result, it is critical to find the best conveyor system to meet the needs of various industries. To sustain productivity, it is necessary to rank the conveyors. In this paper, an attempt has been made to select the most appropriate conveyor utilizing a variety of decision-making methods.

Researchers have worked on strategies for finding the best optimum solution for various selection problems, but conveyor selection using selected methods is not reported. Therefore, the present work aims to the selection process of the best option for conveyor by using four selected decision-making methods such as analytical hierarchy process, technique of order preference by similarity to ideal solution, compromise ranking method and Deng's similarity-based method. The selection is done among four alternatives based on six attributes, viz. fixed cost each hour, variable cost each hour, conveyor speed, product width, product weight and flexibility. The detailed explanation of the problem statement is provided in Sect. 3.1.

2 Related work

Researchers are working in the field of various operational research activities to optimize various industrial processes. The kinds of literature are available on the application of multi-attribute decision-making methods (MADM) to achieve selection among various attributes and alternatives. This section gives some recent studies done on selection problems.

Emovon and Oghenyerov (2020) conducted a detailed review of the MADM methods application in material selection, which was then classified into five categories, viz. type of decision criteria used, type of MADM methods applied and application areas, year of publication of MADM article, types of journals in which the MADM article was published, and MADM techniques country of application. It is found that MADM technique is a very useful tool in making decision with respect to material selection. However, there are still many areas that need to be addressed by other researchers, such as categorizing studies to determine whether the research environment is fuzzy or not, and expanding article searches in various databases to include theses and textbooks. Ghaleb et al. (2020) proposed a methodology for evaluating different selection approaches, including the technique for order of preference by similarity to ideal solution (TOPSIS), analytic hierarchy process (AHP), and Vlsekriterijumska optimizacija Ikompromisno Resenje (VIKOR). Productivity, accuracy, complexity, flexibility, material utilization, quality, and operation cost were the criteria used to evaluate and identify the best manufacturing process. Gravity die casting, investment casting, pressure die casting, sand casting, and additive manufacturing were all considered as manufacturing processes. The proposed approach can be applied to the selection of a complex manufacturing process, has a simpler structure than the technique used, and provides an overall comparative analysis to evaluate different selection approaches. The proposed model may be subjected to multiple layers of manufacturing process selection criteria.

Chaitanya and Srinivas (2019) applied the MADM methods to the piston material selection for optimal design process. On selected MADM methods, a comparative study of subjective and objective criteria weights is carried out. Sensitivity analysis is used to demonstrate consistency in performance score ranking order as the weights of the criteria for each alternative change. The current problem is solved by the ENTROPY and AHP strategies. This assists designers in prioritizing engineering materials based on reality data. Performance scores and ranks are plotted for obtained results for clear perception; the impact of criteria weights on ranking methods is also determined to differentiate various methods. Komatina et al. (2018) investigated the approach of applying mathematical decision-making methods, which can be useful for decision-makers in the decision-making process. The application of multi-criteria decision methods through the basic phases, as well as the classification of exact decision-making methods, is also covered. The analysis of multi-attribute decision-making methods and their application in the selection of process equipment in various fields of industry has received special attention. This study provides guidance for the appropriate selection of equipment that may be suitable for recycling. Future research should look into the impact of newly proposed methods, such as the Best–Worst method.

Veeris et al. (2018) selected potential rural roads for cross-border shipment using the AHP method. Cross-border trade value, distance from border to rural road, agriculture and processed agriculture goods transported across the border, compatibility with national strategies, area characteristics around the rural road, truck volume, and number of rural roads within a 50-km radius of the border are the seven key factors influencing rural road selection. It demonstrates that the cross-border trade value is the most important factor because it receives the most weight. However, route selection cannot be based solely on total weight. The road network and road characteristics must also be considered when deciding on the best road for improvement. Saptari et al. (2021) identified issues in one of the companies that supplies raw materials and electrical parts' procurement department. A delay in delivery occurred between a week and ten working days, causing disruption in the assembly process and delays in customer delivery. As a result, the AHP method is used to find the best supplier. It is also determined which supplier has the best performance in terms of quality, price, delivery, flexibility, and services, so that the company can prioritize the supplier in fulfilling the required electrical parts purchase order.

From the above literature study, it is observed that numerous scientists have dealt with strategies for finding the best optimum solution for their problem statements, but no researchers had worked on the conveyor selection for material handling in process industries using MADM methods such as AHP, TOPSIS, VIKOR and Deng's method. Therefore, in the current work, the attempt is made to track down the ideal ranking using proposed techniques among six attributes and four alternative conveyors.

3 Methodology

The present research work focusses on selection of conveyor from among various attributes and alternatives. Therefore, it is essential to properly identify the important attributes for various alternates. The alternatives can be ranks by applying selected MADM methods and results obtained using selected methods can compared and finally select the best alternatives. Therefore, the present work is executed in four steps and methodology flowchart is shown in Fig. 1:

i. Identify attributes and available alternatives.
ii. Implementation of four selected MADM methods viz.: AHP, TOPSIS, VIKOR, and Deng's similarity-based method.
iii. Solution using selected methods and obtain the results.
iv. Select the best alternative from the given alternatives.

3.1 Identification of attributes and alternatives (Conveyor Selection Problem)

Nowadays, the material handling conveyors plays a very vital role in most of industries. Industries spends millions of dollars for conveyor and therefore proper conveyor must be selected for the material handling. The present work consists of four alternative conveyors (A1, A2, A3 and A4) and six attributes, i.e. fixed cost (FC) per hour, variable cost (VC) per hour, conveyor speed (CS), product width (PW), product weight (W) and flexibility (F). The attributes like CS, PW, W and F are beneficial attributes, while FC and VC are non-beneficial attributes. The quantitative data for six attributes for four alternatives are shown in Table 1.

3.2 MADM methods

The following four selected methods are used to solve conveyor selection problem:

3.2.1 AHP method

This method developed by Thomas Saaty in 1980 is a technique for prioritizing complex and unstructured data in order to obtain the most preferred alternatives using a mathematical approach. It is a frequently used method that has both qualitative and quantitative qualities and may objectively obtain relatively accurate decision-making

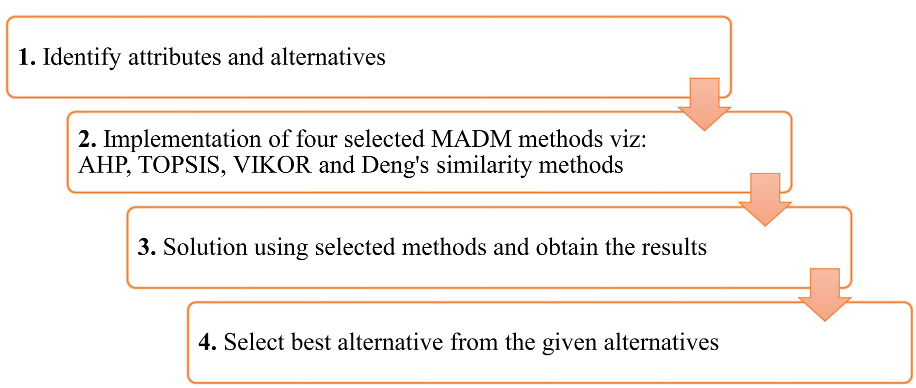

Fig. 1 Methodology flowchart

Table 1 Quantitative data of attributes for alternatives

Conveyors	FC (lacks)	VC (in lacks)	CS (feet/minute)	PW (cm)	W (kg)	F
A1	2	0.45	12	15	10	Very good (0.745)
A2	2.3	0.44	13	20	10	Excellent (0.955)
A3	2.25	0.45	11	30	20	Excellent (0.955)
A4	2.4	0.46	10	25	15	Very good (0.745)

(Wang 2021). It includes a specialized form of solution and uses pairwise comparison to establish relationships within the hierarchical structure. In the decision-making process, each element is subjected to a judgmental approach on its own. The method used to determine the best outranking of alternatives. It is one of the most comprehensive systems for making decisions with multiple criteria as the method allows to formulate the problem as a hierarchical and believe a mixture of quantitative and qualitative criteria.

The fundamental technique of utilizing the mean strategy is as per the following:

Step 1: Develop the hierarchical structure includes objectives, attributes and alternatives.

Step 2: Estimate a pairwise correlation among the attributes with the assistance of a nine-point scale of relative significance as characterized relative importance for the target (Taherdoost 2017). The mean technique is utilized to search out the relative standardized weights of the criteria. The geometric mean (GM) is calculated using Eq. (1).

$$GM_j = [\Pi b_{ij}]^{1/M} \tag{1}$$

where M is the size of the matrix.

The weights (W) are calculated using Eq. (2).

$$W_j = \frac{\mathrm{GM}}{\Sigma \mathrm{GMj}} \tag{2}$$

Step 3: Check the consistency.

The consistency index (C.I.) and the consistency ratio (C.R.) are determined to know the precision of near weights using Eqs. (3 and 4), respectively.

$$CI = \frac{(\lambda_{max} - M)}{(M - 1)} \tag{3}$$

where λ_{max} is the average eigenvalue.

$$CR = \frac{CI}{RI} \tag{4}$$

where R.I. is the random index and it is taken as 1.12. (Taherdoost 2017).

Step 4: Calculate the normalized matrix of each attribute by the local priority.

Step 5: Determine the overall performance rating for the alternatives by multiplying the relative normalized weight (W_n) of each attribute (obtained in Step 2) with its corresponding normalized value for each alternative (obtained in Step 4) and employs summation over all the attributes for each alternative.

3.2.2 TOPSIS method

This strategy follows the idea that the chosen option ought to have the base Euclidean distance from the positive ideal arrangement and most extreme from the negative ideal arrangement. The TOPSIS along these offers the response that is not just nearest to theoretically best, that is additionally the farthest from the theoretically bad (Zulqarnain et al. 2020). This method gives us the best solution as well as rankings of options expressing the significance of TOPSIS for assessment and ranking (Çelikbilek and Fatih 2020).

The principal system of the TOPSIS technique for determination of the best option from among those accessible is depicted below,

Step 1: Create the standardized decision matrix using Eq. (5).

$$r_{\mathrm{ij}} = \frac{x_{\mathrm{ij}}}{\left(x_{\mathrm{ij}}^2\right)} \text{ for } = 1\ldots m;\ j = 1\ldots n \tag{5}$$

Step 2: Create the weighted standardized decision matrix using Eq. (6).

Let us have array of weights for each attribute W_j for j = 1…. n. Take a product of each column of the standardized decision matrix by its related weight.

$$V_{ij} = W_j \times r_{ij} \tag{6}$$

Step 3: Detect ideal best (PIS) and ideal worst (NIS) solutions.

Positive ideal (best) solution: (highest value for beneficial and lowest for non-beneficial attribute) and negative ideal (worst) solution: (lowest value for beneficial and highest for non-beneficial attribute).

Step 4: Compute the separation measure.

Positive separation measures using Eq. (7).

$$S_{i^+} = \sqrt{\sum (V_j{}^+ - V_{ij})^2} \tag{7}$$

Negative separation measures using Eq. (8).

$$S_{i^-} = \sqrt{\sum (V_j^- - V_{ij})^2} \tag{8}$$

Step 5: Compute the relative nearness to the desired ideal solution using Eq. (9).

$$P_i = \frac{S_i^-}{(S_i^- + S_i^+)} \tag{9}$$

Step 6: Rank the preference order.

In this way, the choices are finally positioned in plummeting order and the ranking is acquired. The primary rank got is the nearest answer for ideal arrangement and farthest from negative ideal arrangement. Additionally, the last rank acquired is the farthest arrangement from ideal arrangement and nearest to the negative ideal arrangement.

3.2.3 VIKOR Method

This is a problem-solving and sorting technique for complex systems that optimizes multi-criteria decision making (Kaya 2021). It was created as a multi-attribute decision-making strategy to tackle discrete choice issues with non-commensurable and clashing attributes. This strategy centres on ranking and choosing from a gathering of choices inside the presence of clashing attributes is to help decision-makers to arrive at a definitive objective (Kamble et al. 2022).

The fundamental procedure is as per the following:

Step 1: Identify objective, and to calculate best (X_i^+) and worst (X_i^-) values among all attributes.

Step 2: Calculate the optimal and inferior solution of schemes comprehensive evaluation using Eqs. (10 and 11), respectively.

$$E_i = \sum_{j=1}^{M} \frac{w_j * ((m_{ij})_{max} - m_{ij})}{((m_{ij})_{max} - (m_{ij})_{min})} \tag{10}$$

$$F_i = Max\ of \sum_{j=1}^{M} \frac{w_j * ((m_{ij})_{max} - m_{ij})}{((m_{ij})_{max} - (m_{ij})_{min})} \tag{11}$$

Step 3: Calculate the value of (P) interest's ratio brought by scheme using Eq. (12).

$$P = \frac{v * (E - E_{\min})}{(E_{\max} - E_{\min})} + (1 - v) * \frac{(F - F_{\min})}{(F_{\max} - F_{\min})} \text{ where, the standard value of } v = 0.5 \tag{12}$$

Step 4: Arrange the alternatives according to values of interest ratio in the ascending order.

After the alternatives are arranged according to ranks, the first alternative is the best solution and the last alternative is the worst solution.

3.2.4 Deng's similarity-based method

TOPSIS has the lowest rank in the recreation correlation with the other remaining methods, which is not quite the same as the remaining procedures. In order to overcome this, Deng proposed the concept of other gradient in 2007 to handle the issue of other in multiple attribute examination (Anand et al. 2017).

The step-by-step procedure for Deng's similarity method is portrayed below,

Step 1: Decide the overall significance of various attributes regarding the goal. Make a pairwise correlation matrix utilizing a nine-point scale of relative significance. This step is clarified above in AHP strategy (4.1) solution (step 1).

Step 2: Normalize the decision matrix through Euclidean normalization using Eq. (13).

$$r_{ij} = \frac{x_{ij}}{(\Sigma x^2{}_{ij})} \tag{13}$$

Step 3: Make the weighted standardized choice matrix. Expect that we have an array of weights for every attribute Wj. Take a product of every column of the standardized choice matrix by its related weight using Eq. (13).

$$V_{ij} = W_j \times r_{ij} \tag{14}$$

Step 4: Determine positive ideal solutions (PIS) and negative ideal solutions (NIS) as discussed in TOPSIS method (4.2–step 3).

Step 5: Conflict index between alternative and PIS and NIS:

The degree of clash between alternative (A_i) and (I^+) & (I^-) is expressed by Eqs. (15 and 16), respectively.

$$COS\theta_{i^+} = \frac{y_{ij} * I^+}{\sqrt{\sum y_{ij}^2 * \sum (I_j^+)^2}} \tag{15}$$

$$COS\theta_{i^-} = \frac{y_{ij} * I^-}{\sqrt{\sum y_{ij}^2 * \sum (I_j^-)^2}} \tag{16}$$

Step 6: As per the degree of the clash between the alternative and the PIS and NIS, the degree of similarity of the alternative between alternative (A_i) and (I^+) & (I^-) can be expressed by using Eqs. (17 and 18), respectively.

$$S_{i^+} = \frac{\mathrm{COS}(\theta_i^+) * A_i}{I_j^+} \tag{17}$$

$$S_{i^-} = \frac{\mathrm{COS}(\theta_i^-) * A_i}{I_j^-} \tag{18}$$

Step 7: Calculate the overall index for every alternative across all attributes using Eq. (19).

$$P_i = \frac{S_i^+}{(S_i^+ + S_i^-)} \tag{19}$$

Step 8: Rank the choices according to the overall index in descending order.

3.3 Solutions using MADM methods

3.3.1 AHP method

Step 1: The goal is to select the best conveyor among the given alternatives.

Step 2: Create a correlation matrix among the criteria and calculate geometric mean and weights. Table 2 represents relative importance matrix.

The geometric mean calculation is done by using Eq. (1), and weight calculations are done by using Eq. (2) $W_1 = 0.298$, $W_2 = 0.221$, $W_3 = 0.061$, $W_4 = 0.090$, $W_5 = 0.191$, $W_6 = 0.139$.

Step 3: Check the consistency (weights correct or not)

$$A_1 = \begin{bmatrix} 1 & 2 & 2 & 3 & 3 & 2 \\ 1/2 & 1 & 2 & 3 & 2 & 2 \\ 1/2 & 1/2 & 1 & 1/3 & 1/5 & 1/3 \\ 1/3 & 1/3 & 3 & 1 & 1/3 & 1/2 \\ 1/3 & 1/2 & 5 & 3 & 1 & 2 \\ 1/2 & 1/2 & 3 & 2 & 1/2 & 1 \end{bmatrix} \quad A_2 = \begin{bmatrix} 0.298 \\ 0.221 \\ 0.061 \\ 0.090 \\ 0.191 \\ 0.139 \end{bmatrix}$$

$$A_3 = A_1 \times A_2 \begin{bmatrix} 1.983 \\ 1.423 \\ 0.435 \\ 0.580 \\ 1.256 \\ 0.858 \end{bmatrix} \quad A_4 = \begin{bmatrix} 6.663 \\ 6.443 \\ 7.087 \\ 6.438 \\ 6.583 \\ 6.170 \end{bmatrix}$$

Now, the maximum eigenvalue is calculated by the average of matrix A4 by using Eq. (4).

$$\lambda_{\max} = \frac{A_4}{6} = 6.564$$

$\mathrm{CI} = \frac{(\lambda \max - M)}{(M-1)} = \frac{6.564-6}{6-1} = 0.113$ by using Eq. (5).

$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = \frac{0.113}{1.25} = 0.090$ by using Eq. (6).

As the CR ≥ 0 hence, the decision matrix is right and the above weights are correct.

Step 4: Calculation of normalized weights matrix displayed in Table 3.

Step 5: Calculate overall performance index by multiplying weight for each row of alternatives and ranks are obtained as shown in Table 4

3.3.2 TOPSIS method

Step 1: Create the standardized decision matrix, using Eq. (5).

Step 2: Construct the weighted normalized decision matrix, using Eq. (6) as displayed in Table 5.

Step 3: Determine ideal best (V_j^+) and ideal worst (V_j^-) solutions as displayed in Table 6.

Step 4: Calculate positive (S_i^+) and negative (S_i^-) separation measures using Eqs. (7) and Eq. (8) and the relative nearness to the ideal solution (Pi), using Eq. (11) and find rank the order of conveyors as displayed in Table 7.

3.3.3 VIKOR method

Step 1: To identify objective, and to calculate best (X_i^+) and worst (X_i^-) values among all attributes.

Step 2: Calculate the optimal and inferior solution of schemes comprehensive evaluation, using Eqs. (10 and 11) as displayed in Table 8.

Step 3: Calculate the value of interest ratio (P) brought by scheme, using Eq. (12) and rank the alternatives according to values of interest ratio in the ascending order, as displayed in Table 9.

3.3.4 Deng's similarity-based method

Step 1: Determine the relative importance of different attributes regarding the objective as discussed in the AHP method.

Step 2: Normalizing the decision matrix through Euclidean normalization, using Eq. (13).

Table 2 Relative importance matrix

Attributes	FC	VC	SC	PW	W	F
FC	1	2	2	3	3	2
VC	1/2	1	2	3	2	2
SC	1/2	1/2	1	1/3	1/5	1/3
PW	1/3	1/3	3	1	1/3	1/2
W	1/3	1/2	5	3	1	2
F	1/2	1/2	3	2	1/2	1

Table 3 Normalized weighted matrix in AHP

Conveyor	Attributes					
	FC	VC	SC	PW	W	F
A1	0.298	0.216	0.057	0.045	0.095	0.109
A2	0.259	0.221	0.061	0.060	0.095	0.139
A3	0.265	0.216	0.052	0.090	0.191	0.139
A4	0.248	0.211	0.047	0.075	0.143	0.109

Table 4 Overall performance index and ranking of alternatives in AHP method

Conveyor	OPI	Rank
A1	0.819	4
A2	0.836	2
A3	0.953	1
A4	0.833	3

Table 5 Weighted normalized decision matrix in TOPSIS method

Conveyor	Attributes					
	FC	VC	SC	PW	W	F
A1	0.133	0.110	0.032	0.029	0.066	0.060
A2	0.153	0.108	0.034	0.039	0.066	0.077
A3	0.150	0.110	0.029	0.058	0.133	0.077
A4	0.159	0.113	0.026	0.049	0.100	0.060

Table 6 Ideal best and ideal worst values

Ideal best (V_j^+)	0.133	0.108	0.034	0.058	0.133	0.077
Ideal worst (V_j^-)	0.159	0.113	0.026	0.029	0.066	0.060

Table 7 Positive and negative separation measures, relative nearness to the ideal solution and ranks

Conveyor	Si^+	Si^-	Pi	Rank
A1	0.075	0.027	0.267	3
A2	0.072	0.023	0.240	4
A3	0.018	0.075	0.811	1
A4	0.048	0.038	0.446	2

Table 8 Optimal and Inferior solutions

Conveyor	Attributes							
	FC	VC	SC	PW	W	F	Ei	Fi
A1	0.00	0.11	0.02	0.09	0.19	0.14	0.55	0.19
A2	0.22	0.00	0.00	0.06	0.19	0.00	0.47	0.22
A3	0.19	0.11	0.04	0.00	0.00	0.00	0.34	0.19
A4	0.30	0.22	0.06	0.03	0.10	0.14	0.84	0.30

Step 3: Create the weighted normalized decision matrix, using Eq. (14) as displayed in Table 10.

Table 9 Interest ratio and ranks

Conveyor	E_i	F_i	P	Rank
A1	0.55	0.19	0.21	2
A2	0.47	0.22	0.27	3
A3	0.34	0.19	0.00	1
A4	0.84	0.3	1.00	4
E_{max}, F_{max}	0.84	0.3		
E_{min}, F_{min}	0.34	0.19		

Step 4: Detect positive ideal solutions (PIS) and negative ideal solutions (NIS) as discussed in the TOPSIS method.

Step 5: Conflict index between alternative and PIS and NIS, using Eqs. (15 and 16).

Step 6: Calculate the degree of similarity of the alternative between alternative (A_i) and (I^+) & (I^-), using Eqs. (17 and 18).

Step 7: Calculating overall index (Pi) for every alternative across all attributes, using Eq. (19) and rank the alternatives according to the overall index in the descending order, as displayed in Table 11.

From the above assessments of alternatives of conveyors, the A3 conveyor is found as the best choice for conveyor for the given contextual investigation. Further, distinct values of attributes are utilized in this work for looking at the options of conveyor in satisfying every one of the six attributes. In this way, the technique gives a more practical decision to conveyor selection process.

4 Results and discussion

The present work uses four MADM methods, viz. AHP, TOPSIS, VIKOR, and Deng's similarity-based techniques to detect the best suitable conveyor for material handling. The four alternatives of conveyors are examined with respect to their six specified attributes. Table 12 shows the

Table 10 Weighted normalized decision matrix in Deng's similarity-based method

Conveyor	Attributes					
	FC	VC	SC	PW	W	F
A1	0.133	0.110	0.032	0.029	0.066	0.060
A2	0.153	0.108	0.034	0.039	0.066	0.077
A3	0.150	0.110	0.029	0.058	0.133	0.077
A4	0.159	0.113	0.026	0.049	0.100	0.060

Table 11 Overall performance index and ranks in Deng's similarity-based method

Conveyor	Pi	Rank
A1	0.444	3
A2	0.443	4
A3	0.464	1
A4	0.452	2

Table 12 Ranking obtained by four selected methods

Alternatives	A1	A2	A3	A4
AHP	4	2	1	3
TOPSIS	3	4	1	2
VIKOR	2	3	1	4
Deng's	3	4	1	2

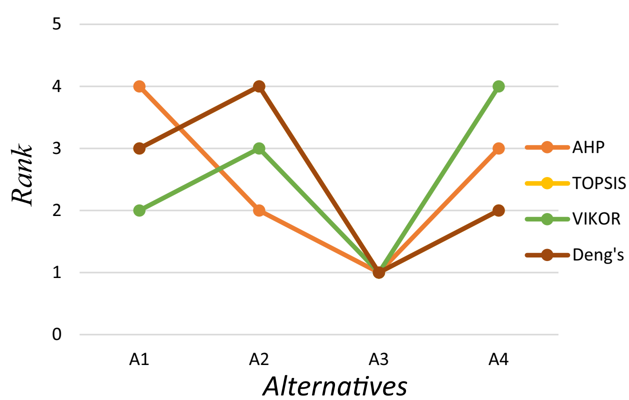

Fig. 2 Comparison chart of ranks

rankings derived using the methodology which can be better displayed and assisting the decision-maker in assessing preferences. The rank obtained by the given methods gives 'A3' as the most suitable conveyor. A similar ranking of the conveyor is acquired by utilizing four selected techniques as displayed in Fig. 2, which shows that the first rank from every technique coming is the 'A3' conveyor which is the best-chosen conveyor. These methods can also be applicable for complex engineering and general applications.

In the AHP method, scoring and ranking depends on the alternatives considered for the evaluation. The removal or addition of alternatives may change the final ranking. The TOPSIS and VIKOR methods lack provision to weigh elicitation and check the consistency of judgements. The TOPSIS method does not consider the relative importance of distances and has the fewest ranks that differ from the remaining methods in the simulation comparison with all other methods. Deng introduced Deng's similarity-based concept of alternative gradient to represent the conflict of alternative in multiple criteria to overcome this problem with analysis.

5 Conclusions and future work

The evaluation of available conveyor and selection of best suitable conveyor is very crucial and important decision for any process industry. The several more conveyors with different properties and specifications are also available. The selection of improper conveyor can directly or indirectly affect the productivity and efficiency of any process industry. Thus, it is important to select the best conveyor for better material handling. The present work shows the easy and logical scientific study to guide any decision-maker for selecting any best alternative. The methodology done in the present work helps decision-maker to take qualitative decision. The four selected decision-making methods, viz. AHP, TOPSIS, VIKOR and Deng's similarity-based methods, are used for solving the proposed problem. The AHP method is used for obtaining weights of all attributes and is applicable for the remaining methods as well. It is found from the ranks obtained using selected methods that A3 conveyor is the best suitable choice for material handling among the four alternatives. It is observed that ranking of conveyor has some deviation in the rankings due to different mathematical approaches used in the four methods. Finally, it is concluded that these methods are very helpful for making decision in complex problems.

The example presented in the current work has demonstrated analytically the computational process of selected methods; however, the analysis is done on the basis of six attributes, and it can be further assessed by including more attributes and alternatives. The problem can be further solved by other decision-making methods for improvement and reliability. Also, the proposed methods can be employed for making the best decision in the other domains of engineering and general administration problems.

Author Contributions Satyam Fulzele and Satywan Khatke conceived of the presented idea. Satyam Fulzele developed the theory and performed the computations. Satywan Khatke and Shubham Kadam verified the analytical methods. Dr. Avinash Kamble encouraged Satyam Fulzele to investigate study of conveyors and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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Data availability The authors declare that they have no data associated with the manuscript.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent I Satyam Fulzele have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I understand that I will be given a copy of this consent form. I voluntarily agree to take part in this study.

Ethical approval I Satyam Fulzele agree and declare that this submission follows the policies of Soft Computing as outlined in the Guide for Authors and in the Ethical Approval.

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