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Research Article

The Selection of Hydraulic Cylinder Using Multi-Attribute Decision-Making Methods

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ABSTRACT

A hydraulic cylinder has an important role in the manufacturing industry for producing unidirectional force through the unidirectional direction. Generally, hydraulic cylinders are used where high-pressure applications are required. It is also called a linear hydraulic motor or mechanical actuator. It is manufactured with closer precisions; thus, it involves higher costs and also, it is desired that hydraulic cylinder work as mentioned design. The main purpose of a hydraulic cylinder is to apply force unidirectional with high pressure. The selection of appropriate Hydraulic Cylinders is a critical task for designers. Designers need to find out precise and required properties of it to fulfil industry demand with desired specifications. Different cylinders possess different properties, so by using an optimization tool we can solve such problems. A systematic approach must be used for the selection of hydraulic cylinders. Thus, in current case study work concentrate on the selection methodology for the best Hydraulic cylinder using four different multi-attribute decision-making methods. The decision-making methods help to predict and rank different hydraulic cylinders.

Keywords: Hydraulic cylinders; Optimization; MADM method; AHP method

INTRODUCTION

Water driven chambers [Hydraulic Cylinders] work on the straightforward guideline of changing over liquid pressing factor energy into mechanical energy. They are excessively known as actuators and have been extensively utilized in a few control gadgets. The functioning strategy for the development of actuator contains water driven chambers [Hydraulic Cylinder] for straight movement, engines for turning movement, pendulum actuators for rotational movement and different sorts of actuators. Water-powered Cylinders participate in uncompromising machines like trucks, JCB, and loaders. Crane, trucks are material handling and drilling equipment, plywood making, bending machines are common industrial applications of a hydraulic cylinder. Hydraulic-powered cylinder gains their influence from compressed pressure-driven liquid, which is normal oil. Subsequently, hydraulic cylinder produce wanted pressing factor for high obligation applications. In the market, there are lots of hydraulic cylinders available which creates confusion during the determination right cylinder for the desired application in any industry. The selection of the wrong cylinder is wastage of money so we have to consider its performance parameters for better results. So, to overcome this selection problem and optimization method called MADM methods are used (Figure 1).

Commonly, we have consistently dealt with the issue in regards to the number of choices for the right dynamic. It is extremely unpredictable and basic to decide a precise decision as indicated by criteria. Such basic dynamic issues are settled by utilizing MADM strategies. Various ascribe, just as choices, settles on the choice interaction complex. Musman AH and Ahmad R [1] pondered the hypothetical connection between information analysis, information formation and making decision in modern cycles. The creators depicted the decision interaction beginning from characterizing the issue to execution of the arrangement and assessment and the

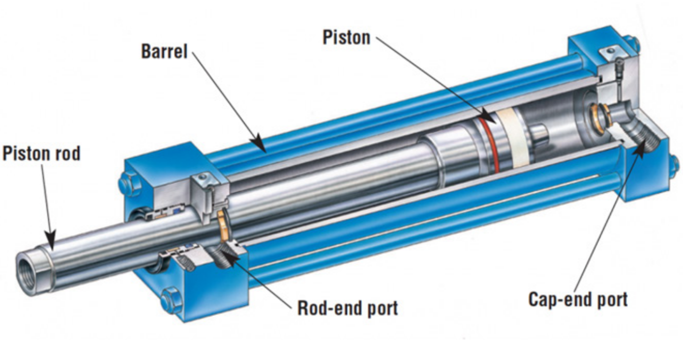

Figure 1: Hydraulic cylinder.

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job of (MADM) strategies in the dynamic decision cycle. These methods provide efficient tools in selection problems when there are several attributes and alternatives. These methods are very useful for decision-makers to capture the varying overall requirements of the selected problem. The Analytical Hierarchy Process (AHP), created by Satty (1990) is the most mainstream and broadly utilized MADM strategy. The technique rots a dynamic issue into an arrangement of orders of objective, standards and options. The COPRAS dynamic procedure acknowledges immediate and corresponding necessities of the importance and worth level of accessible rules under the presence of commonly clashing qualities Zavadskas et al. (2008). All of these methods are very useful to solve critical decision-making problems so that these methods are also called optimization tools. AHP technique is for the most part used to compute loads for the standardized network which assists with discovering wanted determination by looking at the position of various MADM strategies. In a current case study, we used five alternatives for the best selection of hydraulic cylinders.

LITERATURE REVIEW

Many researchers are working in the field of operational research to optimise industrial activities. A great deal of literature is available on the application of MADM methods for the selection of optimum solutions among multiple alternatives and criteria. In this section, some recent studies that use MADM methods in selection problems are reviewed.

Gupta et al. [2] showed that an AHP model of manufacturing sustainability through different manufacturing practices to achieve competitiveness in the market. Popovic et al. [3] explained that the selection of one or more investment projects from the set of possibilities is an important and difficult task for decision-makers. This paper studies the investment projects choice based on different financial analysis criteria and the use of inexact data. Popovic et al. [3] explained that the selection of one or more investment projects from the set of possibilities is an important and difficult task for decision-makers. This paper reflects the investment plans selection based on financial analysis principles and the use of inexact data. In the projected model, the elective venture's still up in the air utilizing fresh and span esteems, and afterwards, the best task from the accessible is chosen by utilizing COPRAS. The efficiency of investment projects can be evaluated by using economic, financial, technological, ecological-environmental and other efficiency indicators Occhipinti and Colombini [4] proposed a new procedure for analysing multiple repetitive tasks by using the OCRA method. And this good practice tool will be useful for professionals interested in risk prevention management of biomedical overload. Kamble and Rao [5] clarified that the selection process of cricket players from a set of six-level players in critical conditions using an analytical hierarchy process and assists with positioning the players. Zhang et al. [6] proposed that Based on the topsis method and gray relational analysis method, they present a combined approach to the multi-attribute group decision making. They showed the Evaluating projects risk assessment is given to show the feasibility and effectiveness of the developed method. The degree of grey relational among the ideal alternative and every comparability alternative is evaluated. Chatterjee and Chakraborty [7] applied concepts of the complex proportional assessment method (COPRAS) and ARAS for the selection of the best alternative based on a different attribute. The authors applied these methods to evaluate alternatives and select the best suitable material for gear manufacturing. Adali and Isik [8] used COPRAS and ARAS concepts to evaluate the air conditioner selection problem with different attributes, i.e., Energy Efficiency Ratio (EER), coefficient of performance, presence of ionizer, cost, greatest sound level (open-air), watts utilization for warming and watts utilization for cooling. Air conditioner choices were positioned by utilizing these two techniques and furthermore the outcomes were looked at for better results.

It has been cleared from the literature review that many researchers have been agitated in solving real-world problems of critical nature using optimization tools i.e., MADM methods. The application areas of these methods are very wide and also these methods are known for solving complex selection problems using multiple attributes and alternatives. However, there is no proof in the literature for the selection of hydraulic cylinders using different MADM techniques. The present case study provides the theoretical framework to select the best cylinder by considering various important properties affecting the working performance of the cylinder. The five alternative cylinders are considered and evaluated based on five important cylinder performance parameters as attributes. The goal and objective of the present case study are to select an appropriate hydraulic cylinder by applying four selected MADM techniques *viz*.: AHP, COPRAS, OCRA, GRA, and comparing the results obtained from chosen MADM strategies to identify the most suitable hydraulic cylinder for the industry.

METHODOLOGY

For a selection of the best and optimum solution for Hydraulic Cylinder, below is the procedure.

- Determination of Alternative and attributes, by considering various types of cylinders and selection criteria.
- Searching for the best rank using AHP, COPRAS, OCRA and GRA Methods.
- Comparing ranks to get the best optimum solution.
- Selection of the best alternative from all methods for decision making.

The below figure illustrates the required methodology (Figure 2).

Methods for solving selection of hydraulic cylinder problem

To solve hydraulic cylinder determination issues the accompanying four straightforward techniques are applied.

AHP method

It's a simple decision making tool to influence critical, unstructured

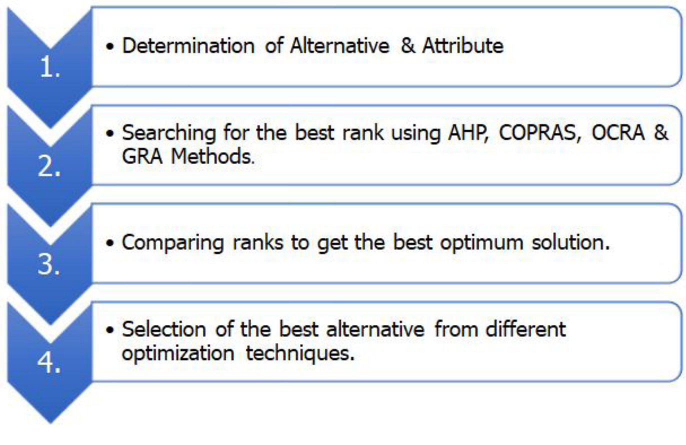

Figure 2: The flow chart of methodology.

and multi attribute issues which were created by TL Saaty Taherdoost H. [9] stated that Analytical Hierarchy Process is extremely valuable way to deal with complex selection issues. AHP break downs a decision-making issue into levels of orders of the goal, attributes and choices. Pacemska T. et al. [10] stated that AHP focuses on the general significance. It's one of the chief mainstream scientific methods for complex decision making issues. The techniques are made out of three stages; first, the construction of the issue; second, the relative arbitrament of the other options and standards; third, assimilation of the needs. The importance of relative weights of each criterion is compared in pairwise examination matrix.

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

Step 1: Decide the objective and assessment attributes.

Step 2: Estimate a pair-wise correlation among the properties with the assistance of a nine-point size of relative significance as characterized in Table 1 of relative significance for the target.

The mean technique for AHP is utilized to search out the relative standardized weights of the criteria.

$$GM_j = \left[\Pi b_{ij}\right]^{1/M} \quad (1)$$

$$W_j = \frac{G\ M}{\Sigma GM_j} \quad (2)$$

Step 3: Determine consistency ratio

The consistency record (C.I.) and the consistency proportion (C.R.) are determined to know the precision of near weights. The Consistency Index (C.I.) is

$$C.I. = \frac{(\lambda_{MAX-M})}{M-1} \quad (3)$$

$$C.R. = \frac{C.I.}{R.I.} \quad (4)$$

Where, value of R.I. is taken from Table 2.

For different matrixes, R.I. is calculated as.

Step 4: Calculate the normalized weight matrix

Step 5: The following stage is to calculate the general or composite performance scores for given criteria. With the help of the fuzzy transformation scale, the worth of the attributes (criteria) is chosen as linguistic terms and then, at that point changed over into related fuzzy numbers at last, changed over to the fresh scores (Table 3).

Step 6: Finally calculate the Rank by comparing it with other methods rank.

Table 1: The nine-point scale of relative importance.

Numerical values of importance	Verbal scale	Description
1	Equal importance	Judgement favours both attributes equally.
3	Moderate significance	Judgement favours slightly one attribute.
5	Solid significance	Judgement favours strongly one attribute.
7	Extremely impressive significance	An activity is capably preferred and its strength is shown by and by.
9	Extreme significance	The proof preferring one action over another is of the most extreme conceivable request of assertion.
2, 4, 6, 8	Immediate qualities between the above values	Absolute judgement cannot be given and a compromise is required.

COPRAS method

The COPRAS method accepts straight and proportional requirements of the significance and value degree of available alternatives under the presence of mutually differing criteria Zavadskas et al. [11]. This method assumes direct and proportional dependences of the significance and utility degree of available alternatives when mutually conflicting criteria are present. It considers the performance of the criteria for various attributes and furthermore the relating standards weights. This method chooses the best choice thinking about both the ideal best and the perfect-worst solutions.

Step 1: Normalize the choice matrix utilizing the direct normalization technique. The reason for normalization is to acquire dimensionless values of various criteria so that all can be compared.

Step 2: Decide the weighted standardized decision matrix, D.

$$D = R_{IJ} + W \quad (5)$$

The amount of dimensionless weighted standardized values of every criterion is consistently equivalent to the weight for that criterion.

$$\sum_{I=1}^{M} \times Y_{IJ} = W \quad (6)$$

Thus, it can be said that the weight, W_J of J^{th} criterion is equally divided among all the alternatives

Step 3: The amount of weighted normalized values are determined for both the beneficial attribute and non-beneficial attribute using the accompanying conditions,

$$S_{+I} = \sum_{J=1}^{N} \times Y+_{IJ} \quad (7)$$

$$S_{-I} = \sum_{J=1}^{N} \times Y-_{IJ} \quad (8)$$

Where $Y+_{IJ}$ and $Y-_{IJ}$ are the weighted normalized qualities for the beneficial and non-beneficial traits individually. The more value of the S_{+I}, the better is the other choice; and the lower the value of S_{-I}, the better is the other alternative (choice).

$$S_+ = \sum_{I=1}^{M} S_{+I} = \sum_{I=1}^{M}\sum_{J=1}^{N} Y_{+IJ} \quad (9)$$

$$S_- = \sum_{I=1}^{M} S_{-I} = \sum_{I=1}^{M}\sum_{J=1}^{N} Y_{-IJ} \quad (10)$$

Table 2: Random index based on some attributes (criteria).

Random index based on some attributes								
Attribute (criteria)	3	4	5	6	7	8	9	10
RI charge	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Table 3: The fuzzy score of the linguistic terms conversion.

Linguistic term	Fuzzy score
Low	0.115
Suboptimal (below expected)	0.295
Normal	0.495
Better than expected	0.695
High	0.895

Step 4: Decide the importance of the alternatives based on characterizing the positive alternative S_{+I} and negative alternative S_{-I} qualities.

Step 5: Decide the overall relative significances or needs (Qi) of the other criteria.

$$Q_I = S_{+I} + \frac{S_{-I(\min)} \sum_{I=1}^{M} S_{-I}}{S_{-I} \sum_{I=1}^{M} (\frac{S_{-I(\min)}}{S_{-I}})} \quad (11)$$

Where $S_{-I(\min)}$ is the minimum worth of S_{-I}. The more value of Qi, the higher is the need for the other alternative.

Step 6: Compute the quantitative utility (Ui) for ith elective.

$$U_i = \left[\frac{Q_i}{Q_{(\max)}}\right] * 100 \quad (12)$$

Where $Q_{(\max)}$ is the super relative importance value. These utility upsides of the choices range from 0% to 100%

From this worth, we can think and compare about the position for all methods.

OCRA method

Occhipinti and Colombini [12] proposed a new procedure for analyzing multiple repetitive tasks by using OCRA method. And this good practice tool will be useful for professionals interested in risk prevention management of biomedical overload. The inclination rating of the options inside the OCRA technique mirrors the decision producer's inclinations for the principles. Other than this, the most benefit of the OCRA technique is that it can manage those MCDM circumstances when the overall loads of the norms are guided into the other options and diverse weight conveyances are allocated to the models for various options just as a portion of the standards don't matter to all other options. The OCRA technique is described as

Step 1: Calculate the aggregate performance of I_{th} criteria.

Mainly focus on non-beneficial attributes

$$\bar{I} = \sum_{J=1}^{N} W_J \frac{\max(X_j^m) - X_J^I}{\min(X_J^M)} [I = 1,2 \ldots M; J = 1,2 \ldots N; I \neq M] \quad (13)$$

Where $\bar{I}_I$ is the relative performance of ith option and X_J^I is the performance score of I_{th} criteria regarding W_J input criteria. The alignment constant W_J (relative significance of J_{th} criteria) is utilized to increment or decrement the effect of this difference on the rating on $\bar{I}_I$ regarding J_{th} criteria.

Step 2: Compute the rating linear preference for input alternatives.

$$\bar{I}_{II} = \bar{I}_I - \min(\bar{I}_I) \quad (14)$$

I addresses the rating aggregate preference for I_{th} criteria regarding the input alternative standards.

Step 3: Determine the rating preference concerning beneficial attributes

The total sum for I_{th} alternative on every one of the benefits is estimated utilizing the following equation,

$$\bar{O}_I = \sum_{h=1}^{H} W_h \frac{X_h^I - \max(X_h^m)}{\min(X_h^m)} \quad (15)$$

Where, h=1, 2...n demonstrates the number of beneficial criteria and W^h is the adjustment constant (weight significance) of h^{th} output criteria. The higher the criteria score for an output criterion, the higher is the preference for that other criterion.

It tends to be notice that $\sum_{J=1}^{N} W_J + \sum_{h=1}^{H} W_h = 1$

Step 4: Compute the straight inclination rating for the output attributes measures accompanying condition,

$$\ddot{O}_I = \bar{O}_I - \min[\bar{O}_I] \quad (16)$$

Step 5: Process the preference overall rating.

The preference overall rating for every criterion is determined by scaling the aggregate $[\bar{I}_{II} + \ddot{O}_I]$ with the goal that the least preferable option gets a rating of nothing.

The preference overall rating (Pi) is determined as follows,

$$P_I = [\bar{I}_{II} + \ddot{O}_I] - \min[\bar{I}_{II} + \ddot{O}_I] \quad (17)$$

From this preference rating, we can calculate rank to find an optimal solution.

GRA method

The Gray Relational Analysis (GRA) technique was previously settled by Deng and has been effectively applied in tackling a spread of MADM issues JS Ma [13] they showed the Evaluating projects risk assessment is given to show the feasibility and effectiveness of the developed method. The key procedure of GRA is first interpreting the performance of all alternatives into a comparability sequence. The main principle of the GRA method is that the selected alternative should have the "largest degree of grey relation" since the positive ideal solution and the "smallest degree of grey relation" from the negative ideal solution. Then, the grey relational coefficient between all comparability sequences and the ideal target sequence is calculated. The procedure of the GRA method to solve the MADM problem.

Step 1: Determine normalization for beneficial and non-beneficial attributes

Beneficial attributes

$$X_I^* = \frac{X_I(k) - \min X_I(k)}{\max X_I(k) - \min X_I(k)} \quad (18)$$

Non-beneficial attributes

$$X_I^* = \frac{\max X_I(k) - X_I(k)}{\max X_I(k) - \min X_I(k)} \quad (19)$$

Step 2: Calculation deviation sequence

$$€ = 1 - X_I^* \quad (20)$$

Step 3: Calculate grey relational coefficient

$$£_I(k) = \frac{\Delta_{\min} + \varepsilon \Delta_{\max}}{\Delta_{OI}(k) + \varepsilon \Delta_{\max}} \quad (21)$$

Where $\varepsilon \Delta_{\max}$ =0.5 as Deviation Coefficient

Step 4: Determine the relative final grades of every criteria

$$v_I = \frac{1}{n} \sum_{k=1}^{n} \omega_k(k) \varepsilon_I(k) \quad (22)$$

Where n is no of alternatives and ω is weights

Step 5: Rank every one of the other options and select the best hydraulic cylinder.

Selection of hydraulic cylinder

As per requirement hydraulic cylinders convert fluid pressure and flow into force. They are available in a market with different styles, sizes, materials, and configurations. But sometimes it's very complex to choose the right hydraulic cylinder for desired pressure. So, in this case, a study we are going through four MADM methods to the best selection of a cylinder [14]. The methods are as AHP (Analytical Hierarchy Process), COPRAS (Complex Proportional Assessment Method), OCRA (Operational Competitiveness Rating Analysis Method) and GRA (Grey Relation Analysis). For that, we are considering five alternatives and five attributes as Maximum Operating Pressure (MOP), Cylinder an Effective Area (CEA), Oil Capacity (OC), Maximum Operating Force (MOF) and Cost (C) [15-17].

Out of which cost is non-beneficial and Maximum Operating Pressure [MOP], Cylinder Effective Area [CEA], Oil Capacity [OC], Maximum Operating Force [MOF] is beneficial attributes [18,19]. More details regarding the case study are given in the below Table 4.

Solution using MADM methods

A solution by AHP:

Step 1: Basically, deciding attributes and alternative after that we have calculate weights using geometric mean method.

$W_j = \frac{GM}{\sum GM_j}$ Using equation (2) we can find normalized weights (Table 5).

Step 2: Next find out consistency ratio equation (4) which is ratio of consistency index equation (3) to random index.

$C.R = \frac{0.1031}{1.11}$

C.R. is 0.0929 which is less than 1 so calculated weights are accepted.

Step 3: Calculate the normalized weight matrix by finding Overall Performance Index (OPI).

Table 4: Case study data for hydraulic cylinder.

Hydraulic cylinders	Max Operating Pressure (MOP)	Cylinder Effective Area (CEA)	Oil Capacity (OC)	Max Operating Force (MOF)	Cost (C)
A1	700	6.5	16	45	20660
A2	100	11.4	29	39.9	15449
A3	340	11.5	29	40.1	10290
A4	500	10.2	25	47	12490
A5	210	8.3	24	45.5	15990

Table 5: Relative importance matrix.

Alternative	MOP	CEA	OC	MOF	C	Normalized Weight[NW]
Max Operating Pressure	1	1/7.	1/5.	1/3.	2	0.072
Cylinder Effective Area	7	1	2	3	3	0.4182
Oil Capacity	5	1/2.	1	3	2	0.2732
Max Operating Force	3	1/3.	1/3.	1	3	0.159
Cost	1/2.	1/3.	1/2.	1/3.	1	0.0776

OPI is determined by sum of products of normalized weights and standard weighted matrix for each alternative.

Lastly, we get rank by comparing it with other alternatives (Table 6).

A solution by COPRAS:

Step 1: Normalize decision matrix as same done in first method $r_{ij} = \frac{x_{ij}}{\sum x_{ij}}$ from given decision matrix (Table 7).

Step 2: The weighted normalized matrix D is calculated using $D = r_{ij} * w_{ij}$ where w_{ij} are weights calculated in AHP method (Table 8).

Step 3: The amount of weighted normalized values is determined for both the beneficial attribute and non-beneficial attribute as S_{+I} and S_{-I} using equation (7) and (8).

Now sum of normalised weightage value are calculated by sum of beneficial creiteria S_+ and sum of non-beneficial criteria S_- with equation (9, 10) (Table 9).

Table 6: Normalization and rank.

Hydraulic cylinders	MOP	CEA	OC	MOF	C	Overall Performance Index (OPI)	Rank
A1	1	0.565	0.552	0.957	0.498	0.65	5
A2	0.143	0.991	1	0.849	0.666	0.8847	2
A3	0.486	1	1	0.853	1	0.9396	1
A4	0.714	0.887	0.862	1	0.824	0.8808	3
A5	0.3	0.722	0.828	0.968	0.644	0.7534	4

Table 7: Calculate normalized decision matrix from linear normalization procedure.

Hydraulic cylinders	MOP	CEA	OC	MOF	C
A1	0.378	0.136	0.13	0.207	0.276
A2	0.054	0.238	0.236	0.183	0.206
A3	0.184	0.24	0.236	0.184	0.137
A4	0.27	0.213	0.203	0.216	0.167
A5	0.114	0.173	0.195	0.209	0.214

Table 8: Weighted normalized decision matrix.

Hydraulic cylinders	MOP	CEA	OC	MOF	C
A1	0.027	0.057	0.036	0.033	0.021
A2	0.004	0.1	0.064	0.029	0.016
A3	0.013	0.1	0.064	0.029	0.011
A4	0.019	0.089	0.056	0.034	0.013
A5	0.008	0.072	0.053	0.033	0.017

Table 9: The amount of weighted standardized qualities.

Hydraulic Cylinders	S+ (Sum of Beneficial criteria)	S-(Sum of Non-beneficial criteria)
A1	0.152	0.021
A2	0.197	0.016
A3	0.207	0.011
A4	0.198	0.013
A5	0.167	0.017
Sum	0.922	0.078

Step 4: Decide the overall relative significances or needs (Qi) of the other criteria and Compute the quantitative utility (Ui) for ith elective with help of equation (11) and (12).

Finally, rank is calculated using comparison procedure (Table 10).

Solution by OCRA:

Firstly, calculate in general maximum, minimum of beneficial and non-beneficial attributes. Also add their respective normalized weights (Table 11).

Step 1: Calculate the aggregate performance of I_{th} criteria for non-beneficial attributes and Compute the rating linear preference for input alternatives with equation (13), (14) i.e. Īi and Īii value respectively.

Step 2: For the rating preference concerning with beneficial attributes Ōi and straight inclination rating for the output attributes Öi. Calculated using equation (15) and (16) respectively (Table 12).

Step 3: For preference overall rating Pi we found average of $[\bar{I}_{ii} + \ddot{O}_I]$ and subtract minimum value of this aggregate from total as done in equation (17) (Table 13).

$$P_I = [\bar{I}_{II} + \ddot{O}_I] - \min[\bar{I}_{II} + \ddot{O}_I]$$

Solution by GRA:

Step 1: Determine normalization for beneficial and non-beneficial attributes as mentioned in equation (18) and (19) (Table 14).

Step 2: Calculation Deviation Sequence using equation (20) by $1 - X_I^*$ (Table 15).

Step 3: Calculate Grey Relational Coefficient as in equation (21) (Table 16).

Step 4: Determine the relative final grades of every criteria and final rank using equation (22) (Table 17).

RESULTS AND DISCUSSION

After solving mentioned MADM methods as AHP, COPRAS, OCRA and GRA. We can make the correct decision regarding the selection of hydraulic cylinders for desired attributes. From the results, it is very clear that cylinder A3 is the best choice. In every method, we got different results and ranks which are changing but the first preference is the same in overall methods. The results

Table 10: The relative significances or priorities (Qi), Quantitative Utility (U) and Rank.

Hydraulic cylinders	MOP	CEA	OC	MOF	C	Qi	Ui	Rank
A1	0.027	0.057	0.036	0.033	0.021	0.1717	60.23937	5
A2	0.004	0.1	0.064	0.029	0.016	0.2314	81.20995	3
A3	0.013	0.1	0.064	0.029	0.011	0.285	100	1
A4	0.019	0.089	0.056	0.034	0.013	0.2511	88.10288	2
A5	0.008	0.072	0.053	0.033	0.017	0.1994	69.95026	4

Table 11: Calculate maximum, minimum and normalized weights.

Hydraulic cylinders	MOP	CEA	OC	MOF	C
A1	700	6.5	16	45	20660
A2	100	11.4	29	39.9	15449
A3	340	11.5	29	40.1	10290
A4	500	10.2	25	47	12490
A5	210	8.3	24	45.5	15990
Maximum	700	11.5	29	47	20660
Minimum	100	6.5	16	39.9	10290
Normalized Weights	0.072	0.4182	0.2732	0.159	0.0776

Table 12: Compute the preference ratings and linear preference rating for Non-beneficial criteria and beneficial criteria.

Hydraulic cylinders	Īi	Īii	Ōi	Öi
A1	0	0	- 0.55165	0.098337
A2	0.0393	0.0393	- 0.46666	0.183328
A3	0.0782	0.0782	- 0.28665	0.363333
A4	0.0616	0.0616	- 0.29592	0.354062
A5	0.0352	0.0352	- 0.64998	0

Table 13: Overall preference rating and rank.

Hydraulic cylinders	Īii+Öi	Pi	Rank
A1	0.0983	0.0631	4
A2	0.2226	0.1874	3
A3	0.4416	0.4063	1
A4	0.4157	0.3805	2
A5	0.0352	0	5

Table 14: Normalization of beneficial and non-beneficial.

Hydraulic cylinders	MOP	CEA	OC	MOF	C
A1	1	0	0	0.718	0
A2	0	0.98	1	0	0.503
A3	0.4	1	1	0.028	1
A4	0.667	0.74	0.692	1	0.788
A5	0.183	0.36	0.615	0.789	0.45

Table 15: Deviation sequence.

Hydraulic cylinders	MOP	CEA	OC	MOF	C
A1	0	1	1	0.282	1
A2	1	0.02	0	1	0.497
A3	0.6	0	0	0.972	0
A4	0.333	0.26	0.308	0	0.212
A5	0.817	0.64	0.385	0.211	0.55

Table 16: Grey relational coefficient.

Hydraulic cylinders	MOP	CEA	OC	MOF	C
A1	1	0.333	0.333	0.64	0.333
A2	0.333	0.962	1	0.333	0.501
A3	0.455	1	1	0.34	1
A4	0.6	0.658	0.619	1	0.702
A5	0.38	0.439	0.565	0.703	0.476
Normalized Weights	0.071989	0.4182	0.27322	0.158965	0.078

Table 17: Final grades and rank.

Hydraulic cylinders	MOP	CEA	OC	MOF	C	Sum	Grade	Ranks
A1	0.072	0.139	0.091	0.102	0.026	0.43	0.086	5
A2	0.024	0.402	0.273	0.053	0.039	0.791	0.1582	2
A3	0.033	0.418	0.273	0.054	0.078	0.856	0.1712	1
A4	0.043	0.275	0.169	0.159	0.055	0.701	0.1402	3
A5	0.027	0.183	0.154	0.112	0.037	0.514	0.1028	4

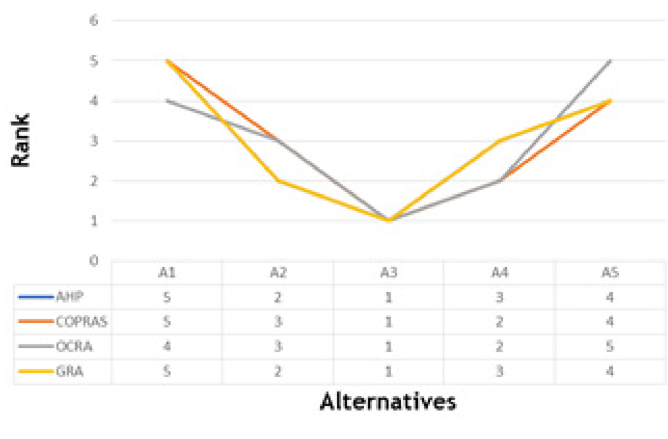

Figure 3: Comparison of rank and alternatives .

also validate that all this method strategy can give exact rankings of chose choices regardless of the complexity of the dynamic decision problems. Thus, the present work discusses four selected techniques and helps to select an appropriate hydraulic cylinder for the industry.

These techniques can also be applied to solve complex selection problems in various industries. The following figure shows a detailed overview regarding the comparison of ranks with different methods (Figure 3).

CONCLUSION AND FUTURE SCOPE

The main objective of the hydraulic cylinder selection problem is to select the best hydraulic cylinder which will satisfy the manufacturer's requirements. There are lots of hydraulic cylinders available in the market with distinct specifications and choosing the best cylinder can be a complicated task amongst difficult conflicting criteria. There is a need for a simple and logical scientific method to guide a user in taking the right decision. In the present case study, selected MADM techniques *viz*. AHP, COPRAS, OCRA and GRA are applied for selecting the best suitable hydraulic cylinder in the industry. The results come from different techniques are assessed and an appropriate hydraulic cylinder based on its properties and specification is identified amongst given alternatives. The given methodology helps decision-makers in selecting an optimum alternative by considering both conflicting quantitative and qualitative selection criteria in real-life applications. The case study presented has demonstrated analytically the computational process of the proposed methods. However, the analysis is done based on five important specifications (criteria).

The decision model exhibited in the present work for a selection of hydraulic cylinders is a general method of MADM. These methods are often employed for creating the simplest decision in other fields of engineering and management problems.

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