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Analysis of Robot Selection Using Fuzzy TOPSIS Method

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Abstract

Industrial robot selection is a decision-making process according to the needs of manufacturing. Making the appropriate choice is crucial to the success and efficiency of the manufacturing. The wrong choice makes it difficult to use the robot or the selected robot is not suitable for many planned production tasks. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical. the result it is seen that Collaborative robot is got the first rank whereas Cylindrical is having the lowest rank.

Key Words: Robot Selection, Fuzzy TOPSIS

1. Introduction

Robots are being used more often in many contemporary manufacturing facilities. Robots do repetitive, demanding, and hazardous jobs with accuracy, and when used appropriately, they may substantially enhance quality and efficiency. As a result, decision-makers see robot selection and application as critical issues. Manufacturing robot selection requires a thorough examination and assessment of the demands in connection to the features of the alternative issue since they are frequently expensive and have a variety of attributes. This process is facilitated by the use of quantitative tools [1]. A new, comprehensive technique for picking a robot is necessary, one that takes into account both technical and consumer criteria. The current work adds and is innovative in the sense that it is simple to use: It does not involve complicated mathematics and covers technological requirements, client requirements, and the economics of robot systems [2]. In today's technologically advanced world Increase productivity and reduce production costs In developing automated systems Most industries focus on In addition, managers in today's competitive market To make essential decisions for their companies, especially in areas where technology decisions are crucial, such the selection of robots [3]. Several studies in the open literature have concentrated on complex models created. A simple, systematic and fair scientific method or a mathematical tool for decision makers (DMs). It should help to reach an acceptable result.

2. Robot Selection

The objective of a robot selection process is determining Robot Selection Factor is to get the best combination of elements relevant to the actual needs of the industry.In order to enhance the current robot selection process, For a specific industrial application Factors influencing the selection of a robot Need to identify, apply logic to the process, eliminate inappropriate robots, and select an appropriate robot[4].Since the first publications in the late 1970s, there are now more robotic devices available on the market for a variety of uses than ever before. There are also more methods available to help the decision-maker choose the right device.Based on these approaches to evaluate some qualities of various solutions reflect objective and repeatable procedures, Expression of robot performance characteristics or economic evaluations[5].In Evolution's OP Robot Performance Parameters To reduce the impact of measurement errors, Robot evaluation within reachable robot joint surfaces Robot evaluation within reachable robot joint surfaces In creating a group of configurations The difficulty is qualitatively defined [6].Decision makers must identify and pick the ideal robot to produce the target result while taking into account many competing factors.MCDM approaches have been developed and utilised in a variety of sectors [7]. It has become difficult to select a robot from the vast array of market options. Subsequently, Since robots are still a new concept in the market, It is common for a company to purchase its first robot Given this tendency And to evaluate robots to select the best robot A process for ranking also seems necessary[8].Robot qualities and their interrelationships, as well as performance measurement criteria, are critical factors in robot selection.The aims and objectives of the enterprise, as well as the requirements of the existing program, dictate the exact criteria that the potential robots must adhere to [9].A robot selection choice is often defined by the two unique qualities listed below.Group decision-making (GDM) is a challenging process since reaching consensus is usually difficult, especially when the specialists have varying levels of technical ability. Second, robot selection may have a big influence on a business. The cost of acquiring a robot typically accounts for a significant portion. Poor robot selection equipment productivity and in terms of product quality Harms a company's competitiveness [10]. A comprehensive investigation and assessment of the criteria as well as the qualities of the alternatives are required because robot installation and purchase involve a sizable initial expenditure, and this can only be done by using quantitative techniques.The problem's complexity becomes obvious when one realises that there are over 75 criteria to consider when selecting a robot for a certain practical applications [11]. Because of the growing interest in the use of robots in education, a wide range of diverse robotic devices with various technological specifications and interaction capabilities have been developed. For the robot-assisted teaching method to be of higher quality, the right social robot must be selected.This social robot selection must include technological and pedagogical factors that are specific to each educational context [12].As there are many great players in the field of robot design and manufacturing A potential robot user today is faced with many options The decision regarding robot selection has become more complex. To complicate matters further, Both should be evaluated based on The problem of robot selection is a complex one To be determined, there are no industry-wide standards for this [13]. Accuracy based assessment Not applicable. Evaluations on Ambiguous Linguistic Variables As is often done, various linguistics A fuzzy to integrate ratings and weights A multi-criteria decision-making process is required Robot fit Select the best candidate [14]. The term robot has various definitions and understandings depending on the individual's profession and/or background. This confusion is fuelled in part by the fact that there are very few standards in the field of robotics. The literature on robotics lacks clarity about at what point a given process variable or attribute interacts with others to cause these changes. In fact, robot specifications are the beginning of this drawback [15]. Several parameters are used to describe robots in the literature. According to Grover et al., it is beneficial to categorise the list of technical features into two groups: "mandatory" and "desirable."'Mandatory' features are those that a robot must have in order to function properly. Those that are "more useful during installation and/or operation" but are not required completing any task. Cost, security, and vendor-related concerns could all be on this list. [16].

3. FUZZY TOPSIS

Any real-world decision-making In the problem, objective and subjective data sets A situation arises that we need to consider The case is an objective data set The case is an objective data set If only included, traditional MCDM tools and techniques can solve the problem. Nevertheless, when both objective and subjective data sets have to be explored and analyzed simultaneously, it becomes a difficult task [17]. In real life, subjective characteristics Measurements, e.g. Human-Machine Interface Programming flexibility Precisely by decision makers May not be defined. Additionally, robot fit and subjective criteria The weights of the criteria are usually linguistic are basically expressed [18]. In making better decisions For Decision Makers (DMs) Direct to help of a rational mathematical instrument There is a need; The committee will decide Under Fuzzy TOPSIS approach The weights of the criteria are usually linguistic are basically expressed [19]. In order to solve complicated, ill-defined situations with various and connected criteria, decision makers might use a complete set of methodologies known as multi-criteria decision making (MCDM). Decision-making under many, frequently contradictory criteria is referred to as MCDM. Each criteria may be measured using a different unit, have a different quality characteristic, and have a different relative weight.Some factors can only be measured; others can only be expressed subjectively. Making informed decisions requires properly framing complex challenges and taking multiple factors into account [20]. In fuzzy MCDM problems, criteria/attribute values and associated weights are usually characterized by fuzzy numbers. A fuzzy number is a convex fuzzy set that is characterized by a given interval of real numbers, each having membership rank between 0 and 1[21]. By using fuzzy numbers instead of precise numbers, the merit of Fuzzy TOPSIS is to provide the importance of attributes and the performance of alternatives with respect to various attributes. In applying TOPSIS, there are necessary steps that involve numerical measurements of the relative importance of attributes and the performance of each alternative on these attributes. However, accurate data may be difficult to determine precisely because human judgments are often ambiguous under many conditions [22]. A weighted summation of some local criteria that have been adjusted based on the beginning conditions might be thought of as a fuzzy extension of the traditional TOPSIS technique.In many real-world scenarios, a weighted sum is not the optimum method for a set of local requirements [23].It can be challenging the decision-maker to give a precise performance evaluation in place of the attributes being taken into account. The benefit of utilising a fuzzy method is that it uses fuzzy numbers rather than precise numbers to determine the relative value of qualities[24]. Strong mathematical methods for modelling uncertain systems in industry include fuzzy sets and fuzzy logic. While sets permit partial participation, crisp sets only permit complete membership or none at all [25].It is challenging to effectively portray using soft data the significance of the decision makers' criteria and the influence of alternatives on the supplier selection dilemma.Integration of expert perspectives is essential for effective execution of the assessment process.For the supplier selection process, the TOPSIS technique in combination with an understandable fuzzy set has a strong likelihood of success [26]. The MCGDM issue must be applied using Fuzzy TOPSIS, and the selection criteria must be the same. If and only if a criterion is preferred, an alternative is the sole criterion if it earns a higher (lower) score than a lower (higher) score on that criterion.Monotonic criteria fall under the categories of costs or benefits. If the candidate performs better on a criterion, it might be categorised as beneficial.The most preferred applicant, however, receives the lowest cost score, according to the cost criterion [27].

4. Analysis and Discussion

TABLE 1. TOPSIS Robot Selection

	Better quality and consistency	Maximum productivity	Greater safety	labour costs
Articulated arm	55.88	68.22	26.33	42.78
Six-axis	84.55	80.33	28.66	52.31
Collaborative robot.	70.22	85.33	30.44	38.45
SCARA	66.44	60.77	31.68	32.56
Cylindrical	54.33	58.66	24.88	54.98

This Table 1 shows data set of robot selection. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical. For better quality and consistency, six-axis is having the best value and for maximum productivity, collaborative robot is having the greatest value and SCARA is having the best value for greater safety. Labour costs value is highest for cylindrical.

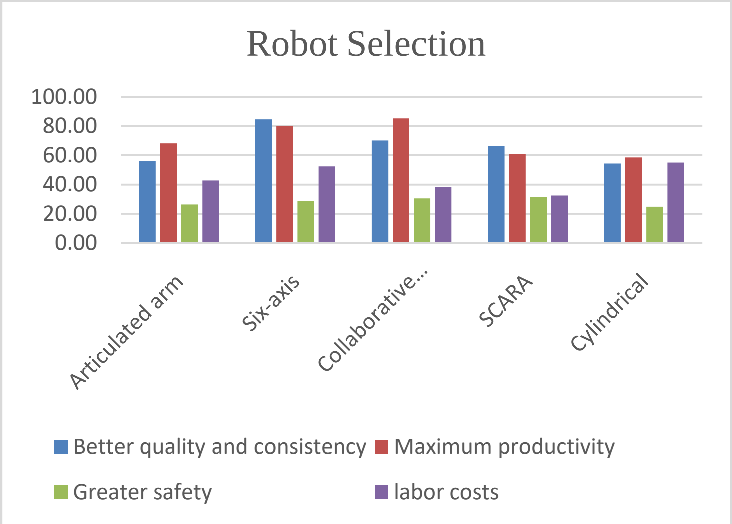

FIGURE 1. Robot Selection in Fuzzy TOPSIS method on the data set.

This figure 1 shows data set of robot selection. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical. For better quality and consistency, six-axis is having the best value and for maximum productivity, collaborative robot is having the greatest value and SCARA is having the best value for greater safety. Labour costs value is highest for cylindrical.

TABLE 2. Squire Rote of matrix

3122.5744	4653.9684	693.2689	1830.1284
7148.7025	6452.9089	821.3956	2736.3361
4930.8484	7281.2089	926.5936	1478.4025
4414.2736	3692.9929	1003.6224	1060.1536
2951.7489	3440.9956	619.0144	3022.8004

Table shows the square root value decision matrix.

TABLE 3. Fuzzy Significance

		l	m	u
Extremely low	EL	0	0	0.1
very low	VL	0	0.1	0.3
low	L	0.1	0.3	0.5
medium	M	0.3	0.5	0.7
high	H	0.5	0.7	0.9
very high	VH	0.7	0.9	1
Extremely high	EH	0.9	1	1

Table 3 shows the importance of weights Collect ratings. The following table using the subjective evaluations of the decision maker fuzzy significance coefficients or calculate the weights equations. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 4. The criteria's on a linguistic scale

	DM1	**DM2**	**DM3**
M1	EH	VL	M
M2	L	EH	VH
M3	L	M	VH
M4	L	M	VL

Table 4 shows the criteria is on a linguistic scale. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 5. Selected ambiguities The Linguistics of Decision Makers Using Convert estimates to quantitative values number.

	DM1			**DM2**			**DM3**		
Better quality and consistency	0.9	1	1	0	0.1	0.3	0.3	0.5	0.7
Maximum productivity	0.1	0.3	0.5	0.9	1	1	0.7	0.9	1
Greater safety	0.1	0.3	0.5	0.3	0.5	0.7	0.7	0.9	1
labour costs	0.1	0.3	0.5	0.3	0.5	0.7	0	0.1	0.3

Table 5 shows the Using the selected Linguistic evaluations of decision makers convert to quantitative values fuzzy number. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 6. Calculate aggregated Fuzzy weights

	L-FW	M-FW	U-FW
Better quality and consistency	0.40	0.53	0.67
Maximum productivity	0.57	0.73	0.83
Greater safety	0.37	0.57	0.73
labour costs	0.13	0.30	0.50

Table 6shows the Calculate aggregated Fuzzy weights food, water, Antibiotics, agriculture Land. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

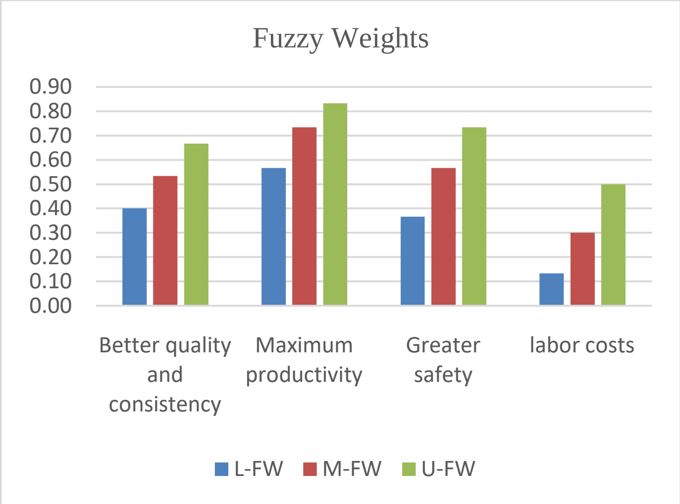

FIGURE 2. Fuzzy weights

Figure 2 shows the graphical representation the aggregated Fuzzy weights. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 7. Normalized Data

Normalized Data			
Better quality and consistency	Maximum productivity	Greater safety	labour costs
0.3720	0.4541	0.4130	0.4251
0.5628	0.5347	0.4496	0.5198
0.4674	0.5680	0.4775	0.3821
0.4423	0.4045	0.4970	0.3235
0.3617	0.3905	0.3903	0.5463

Table 7 shows the normalized matrix for the decision matrix by using Fuzzy TOPSIS method. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 8. Weighted normalized decision matrix

Weighted normalized decision matrix											
Better quality and consistency			Maximum productivity			Greater safety			labour costs		
0.148788	0.198384	0.24798	0.257331	0.333016	0.378427	0.151444	0.234049	0.302887	0.056679	0.127528	0.212546
0.225126	0.300168	0.37521	0.30301	0.392131	0.445603	0.164845	0.254761	0.32969	0.069305	0.155937	0.259894
0.18697	0.249294	0.311617	0.321871	0.416539	0.473339	0.175083	0.270583	0.350167	0.050942	0.11462	0.191033
0.176906	0.235874	0.294843	0.229229	0.296649	0.337101	0.182216	0.281606	0.364431	0.043139	0.097062	0.161769
0.144661	0.192881	0.241102	0.22127	0.286349	0.325396	0.143104	0.22116	0.286207	0.072843	0.163896	0.27316

Table 8 shows the weighted normalized array by using Fuzzy TOPSIS method. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 9. A+ & A-

A +	0.225126	0.300168	0.37521	0.321871	0.416539	0.473339	0.143104	0.22116	0.286207	0.043139	0.097062	0.161769
A-	0.144661	0.192881	0.241102	0.22127	0.286349	0.325396	0.182216	0.281606	0.364431	0.072843	0.163896	0.27316

Table 9 shows the A+ and A- values. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 10. FPIS

FPIS	Articulated arm	0.103883	0.081955	0.013088	0.03507
	Six-axis	0	0.023949	0.03412	0.067773
	Collaborative robot.	0.051923	0	0.050187	0.020212
	SCARA	0.06562	0.117639	0.06138	0
	Cylindrical	0.109499	0.127746	0	0.076935

Table 10. Shows the coordinates for the fuzzy positive ideal solution (FPIS). Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 11. FNIS

FNIS	Articulated arm	0.005616	0.045791	0.048291	0.041865
	Six-axis	0.109499	0.103796	0.02726	0.009162
	Collaborative robot.	0.057576	0.127746	0.011193	0.056723
	SCARA	0.043879	0.010107	0	0.076935
	Cylindrical	0	0	0.06138	0

Table 11. Shows the coordinates for the fuzzy Negative ideal solution (FNIS). Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 12. Si+ & Si-

	Si+	Si-
Articulated arm	0.233996	0.141563
Six-axis	0.125842	0.249717
Collaborative robot.	0.122322	0.253238
SCARA	0.244638	0.130921
Cylindrical	0.31418	0.06138

Table 12. Shows the S+, S- value. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

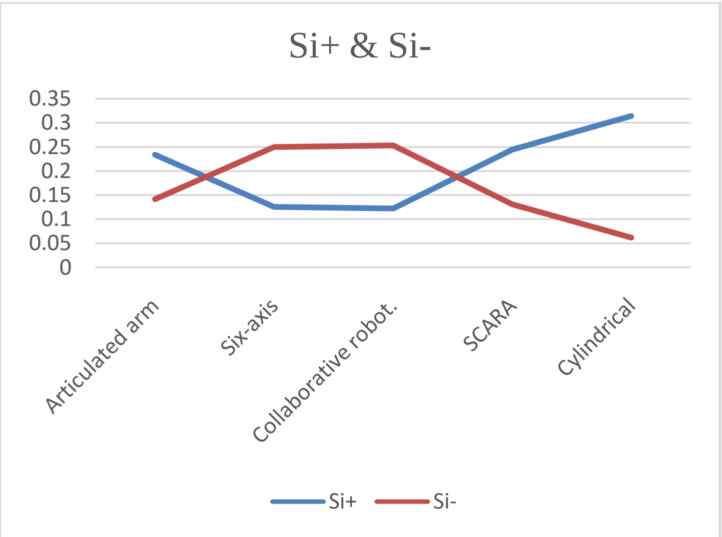

FIGURE 3. Si+ & Si-

Figure 3 shows the graphical representation S+, S- value. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

TABLE 13. Cci

	Cci
Articulated arm	0.37694
Six-axis	0.664921
Collaborative robot.	0.674294
SCARA	0.348602
Cylindrical	0.163435

Table 13 shows rank as per descending order. Alternative: Better quality and consistency, Maximum productivity, Greater safety, labour costs. Evaluation Preference: Articulated arm, Six-axis, Collaborative robot, SCARA, Cylindrical.

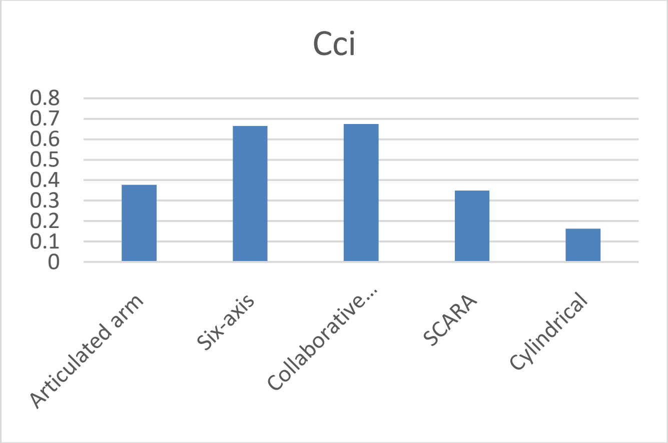

FIGURE 4. Cci

TABLE 13. Rank

	Rank
Articulated arm	3
Six-axis	2
Collaborative robot.	1
SCARA	4
Cylindrical	5

Shows the figure 13 rank of this paper the Collaborative robot 1nd rank Six-axis is in 2nd rank, Articulated arm is in 3th rank , SCARA is in 4rd rank and Cylindrical cases is in 5th rank. The result is done by using the Fuzzy TOPSIS method.

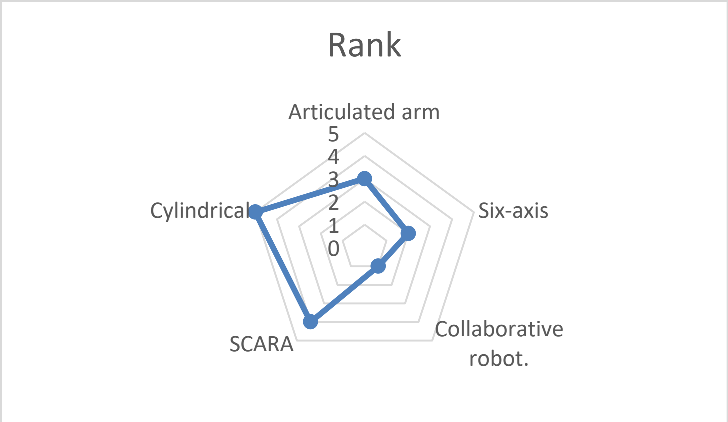

FIGURE 5. Rank

Shows the figure 5 final result of this paper the Collaborative robot 1nd rank Six-axis is in 2nd rank, Articulated arm is in 3th rank , SCARA is in 4rd rank and Cylindrical cases is in 5th rank. The result is done by using the Fuzzy TOPSIS method.

5. Conclusion

There are numerous robots with various specifications, so deciding which the best iscan be complicated depending on many conflicting criteria. The increased usage of robots in different modern industrial processes is mostly due to recent advancements in engineering science and information technology. Robots are being developed by manufacturers to carry out precise, dangerous, and time-consuming jobs in a variety of industrial settings. Consequently, raise product quality and productivity.The decision maker (DM) must take into account a variety of qualitative and quantitative criteria when selecting a robot. These criteria are either maximisation (useful) or minimization (useless). Because of this, MCDM tools are great solutions for issues involving multiple conflicting criteria.

Reference

[1]. Parkan, Celik, and Ming-Lu Wu. "Decision-making and performance measurement models with applications to robot selection." *Computers & Industrial Engineering* 36, no. 3 (1999): 503-523.

[2]. Bhattacharya, Arijit, Bijan Sarkar*, and Sanat Kumar Mukherjee. "Integrating AHP with QFD for robot selection under requirement perspective." *International journal of production research* 43, no. 17 (2005): 3671-3685.

[3]. Goswami, Shankha Shubhra, Dhiren Kumar Behera, Asif Afzal, Abdul Razak Kaladgi, Sher Afghan Khan, Parvathy Rajendran, Ram Subbiah, and Mohammad Asif. "Analysis of a robot selection problem using two newly developed hybrid MCDM models of TOPSIS-ARAS and COPRAS-ARAS." *Symmetry* 13, no. 8 (2021): 1331.

[4]. Kentli, A. Y. K. U. T., and A. K. Kar. "A satisfaction function and distance measure based multi-criteria robot selection procedure." International Journal of Production Research 49, no. 19 (2011): 5821-5832.

[5]. Amici, Cinzia, Nicola Pellegrini, and Monica Tiboni. "The robot selection problem for mini-parallel kinematic machines: A task-driven approach to the selection attributes identification." *Micromachines* 11, no. 8 (2020): 711.

[6]. Zhuang, Hanqi, Jie Wu, and Weizhen Huang. "Optimal planning of robot calibration experiments by genetic algorithms." *Journal of Robotic Systems* 14, no. 10 (1997): 741-752.

[7]. Zhou, Fuli, Xu Wang, and Mark Goh. "Fuzzy extended VIKOR-based mobile robot selection model for hospital pharmacy." *International Journal of Advanced Robotic Systems* 15, no. 4 (2018): 1729881418787315.

[8]. Nasrollahi, Mahdi, Javaneh Ramezani, and Mahmoud Sadraei. "A FBWM-PROMETHEE approach for industrial robot selection." *Heliyon* 6, no. 5 (2020): e03859.

[9]. Koulouriotis, D. E., and M. K. Ketipi. "Robot evaluation and selection Part A: an integrated review and annotated taxonomy." *The International Journal of Advanced Manufacturing Technology* 71, no. 5 (2014): 1371-1394.

[10]. Fu, Yelin, Ming Li, Hao Luo, and George Q. Huang. "Industrial robot selection using stochastic multicriteria acceptability analysis for group decision making." *Robotics and Autonomous Systems* 122 (2019): 103304.

[11]. Athawale, Vijay Manikrao, and Shankar Chakraborty. "A comparative study on the ranking performance of some multi-criteria decision-making methods for industrial robot selection." *International journal of industrial engineering computations* 2, no. 4 (2011): 831-850.

[12]. Papakostas, George A., Athanasios K. Strolis, Fotis Panagiotopoulos, and Charalabos N. Aitsidis. "Social robot selection: a case study in education." In *2018 26th international conference on software, telecommunications and computer networks (SoftCOM)*, pp. 1-4. IEEE, 2018.

[13]. Kapoor, Vikas, and Shyam Singh Tak. "Fuzzy application to the analytic hierarchy process for robot selection." *Fuzzy Optimization and Decision Making* 4, no. 3 (2005): 209-234.

[14]. Liang, Gin-Shuh, and Mao-Jiun J. Wang. "A fuzzy multi-criteria decision-making approach for robot selection." *Robotics and Computer-Integrated Manufacturing* 10, no. 4 (1993): 267-274.

[15]. Offodile, O. Felix, and William Acar. "Comprehensive situation mapping for robot evaluation and selection." *International Journal of Operations & Production Management* (1993).

[16]. Kumar, Rishi, and R. K. Garg. "Optimal selection of robots by using distance based approach method." *Robotics and Computer-Integrated Manufacturing* 26, no. 5 (2010): 500-506.

[17]. Chu, T-C., and Y-C. Lin. "A fuzzy TOPSIS method for robot selection." *The International Journal of Advanced Manufacturing Technology* 21, no. 4 (2003): 284-290.

[18]. Vahdani, Behnam, S. Meysam Mousavi, and Reza Tavakkoli-Moghaddam. "Group decision making based on novel fuzzy modified TOPSIS method." *Applied Mathematical Modelling* 35, no. 9 (2011): 4257-4269.

[19]. Zavadskas, Edmundas Kazimieras, Abbas Mardani, Zenonas Turskis, Ahmad Jusoh, and Khalil MD Nor. "Development of TOPSIS method to solve complicated decision-making problems—an overview on developments from 2000 to 2015." *International Journal of Information Technology & Decision Making* 15, no. 03 (2016): 645-682.

[20]. Wang, Ying-Ming, and Taha MS Elhag. "Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment." *Expert systems with applications* 31, no. 2 (2006): 309-319.

[21]. Chen, Ting-Yu, and Chueh-Yung Tsao. "The interval-valued fuzzy TOPSIS method and experimental analysis." *Fuzzy sets and systems* 159, no. 11 (2008): 1410-1428.

[22]. Dymova, Ludmila, Pavel Sevastjanov, and Anna Tikhonenko. "An approach to generalization of fuzzy TOPSIS method." *Information Sciences* 238 (2013): 149-162.

[23]. Sun, Chia-Chi, and Grace TR Lin. "Using fuzzy TOPSIS method for evaluating the competitive advantages of shopping websites." *Expert Systems with Applications* 36, no. 9 (2009): 11764-11771.

[24]. Torlak, Gokhan, Mehmet Sevkli, Mehmet Sanal, and Selim Zaim. "Analyzing business competition by using fuzzy TOPSIS method: An example of Turkish domestic airline industry." *Expert Systems with Applications* 38, no. 4 (2011): 3396-3406.

[25]. Boran, Fatih Emre, Serkan Genç, Mustafa Kurt, and Diyar Akay. "A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method." *Expert systems with applications* 36, no. 8 (2009): 11363-11368.

[26]. Bottani, Eleonora, and Antonio Rizzi. "A fuzzy TOPSIS methodology to support outsourcing of logistics services." *Supply Chain Management: An International Journal* (2006).