



# Maximizing efficiency and collaboration: Comparing Robots and Cobots in the Automotive Industry – A Multi-Criteria Evaluation Approach

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## References

- [1] M. Javaid and A. Haleem, "Critical Components of Industry 5.0 Towards a Successful Adoption in the Field of Manufacturing," *J. Ind. Intg. Mgmt.*, vol. 5, no. 3, pp. 327-348, 2020, doi: 10.1142/S2424862220500141.
- [2] A. P. Calitz, P. Poisat, and M. Cullen, "The future African workplace: The use of collaborative robots in manufacturing," *SA J. Hum. Resour. Manag.*, vol. 15, p. a901, 2017, doi: 10.4102/sajhrm.v15i0.901.
- [3] G. F. Prassida and U. Asfari, "A conceptual model for the acceptance of collaborative robots in industry 5.0," *Procedia Computer Science*, vol. 197, pp. 61-67, 2022, doi: 10.1016/j.procs.2021.12.118.
- [4] P. Kopacek, "Development Trends in Cost Oriented Production Automation," *IFAC-PapersOnLine*, vol. 51, no. 30, pp. 39-43, 2018, doi: 10.1016/j.ifacol.2018.11.242.
- [5] International federation of robotics, Ed., *World robotics 2022: industrial robots*. Frankfurt: VDMA Services GmbH, 2022.
- [6] S. Proia, R. Carli, G. Cavone, and M. Dotoli, "Control Techniques for Safe, Ergonomic, and Efficient Human-Robot Collaboration in the Digital Industry: A Survey," *IEEE Transactions on Automation Science and Engineering*, vol. 19, no. 3, pp. 1798-1819, 2022, doi: 10.1109/TASE.2021.3131011.
- [7] A. Chacón, P. Ponsa, and C. Angulo, "Cognitive Interaction Analysis in Human-Robot Collaboration Using an Assembly Task," *Electronics*, vol. 10, no. 11, p. 1317, 2021, doi: 10.3390/electronics10111317.
- [8] M. R. Fathi, H. Safari, and A. Faghieh, "Integration of Graph Theory and Matrix Approach with Fuzzy AHP for Equipment Selection," *Journal of Industrial Engineering and Management*, vol. 6, no. 2, pp. 477-494, 2013, doi: 10.3926/jiem.403.
- [9] Emergen Research, "Cobots Market," Emergen Research, Surrey, British Columbia, Canada, Report ID: ER\_0065, 2020. Accessed: May 20, 2023. [Online]. Available: <https://www.emergenresearch.com/industry-report/cobots-market>
- [10] D.-Y. Chang, "Applications of the extent analysis method on fuzzy AHP," *European Journal of Operational Research*, vol. 95, no. 3, pp. 649-655, 1996, doi: 10.1016/0377-2217(95)00300-2.
- [11] M. Javaid, A. Haleem, R. P. Singh, S. Rab, and R. Suman, "Significant applications of Cobots in the field of manufacturing," *Cognitive Robotics*, vol. 2, pp. 222-233, 2022, doi: 10.1016/j.cogr.2022.10.001.
- [12] O. Salunkhe, O. Stensöta, M. Åkerman, Å. F. Berglund, and P.-A. Alveflo, "Assembly 4.0: Wheel Hub Nut Assembly Using a Cobot," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 1632-1637, 2019, doi: 10.1016/j.ifacol.2019.11.434.
- [13] R. Jesuthasan and J. W. Boudreau, *Reinventing Jobs: A 4-Step Approach for Applying Automation to Work*. Boston, MA, USA: Harvard Business Review, 2018.
- [14] H. Mouhib, S. Amar, S. Elrhanimi, and L. E. Abbadi, "An Extended Review of the Manufacturing Transition Under the Era of Industry 5.0," in *2023 7th IEEE Congress on Information Science and Technology (CiSt)*, Dec. 2023, pp. 709-714. doi: 10.1109/CiSt56084.2023.10410003.
- [15] J. Edward, W. Wannasuphprasit, and M. Peshkin, "Cobots: Robots For Collaboration With Human Operators," in *ASME 1996 International Mechanical Engineering Congress and Exposition*, Atlanta, GA, USA, 1996, pp. 433-439, doi: 10.1115/IMECE1996-0367.

- [16] R. J. Rabelo, S. P. Zambiasi, and D. Romero, "Softbots 4.0: Supporting Cyber-Physical Social Systems in Smart Production Management", *Int J Ind Eng Manag*, vol. 14, no. 1, pp. 63-93, 2023, doi: 10.24867/IJIEM-2023-1-325.
- [17] S. El Zaatari, M. Marei, W. Li, and Z. Usman, "Cobot programming for collaborative industrial tasks: An overview," *Robotics and Autonomous Systems*, vol. 116, pp. 162-180, 2019, doi: 10.1016/j.robot.2019.03.003.
- [18] C. T. Landi, V. Villani, F. Ferraguti, L. Sabattini, C. Secchi, and C. Fantuzzi, "Relieving operators' workload: Towards affective robotics in industrial scenarios," *Mechatronics*, vol. 54, pp. 144-154, 2018, doi: 10.1016/j.mechatronics.2018.07.012.
- [19] F. Sherwani, M. M. Asad, and B. S. K. K. Ibrahim, "Collaborative Robots and Industrial Revolution 4.0 (IR 4.0)," in *2020 International Conference on Emerging Trends in Smart Technologies (ICETST)*, Mar. 2020, pp. 1-5. doi: 10.1109/ICETST49965.2020.9080724.
- [20] A. Board, "Collaborative robots: future of the industry," *Pictet Asset Management*. [Online]. Available: <https://am.pictet/en/us/global-articles/2019/expertise/thematic-equities/future-of-robotics-industry> [Accessed: May 20, 2023].
- [21] R. Ojstersek, B. Buchmeister, and A. Javernik, "The Importance of Cobot Speed and Acceleration on the Manufacturing System Efficiency," *Procedia Computer Science*, vol. 217, pp. 147-154, 2023, doi: 10.1016/j.procs.2022.12.210.
- [22] Z. M. Bi, C. Luo, Z. Miao, B. Zhang, W. J. Zhang, and L. Wang, "Safety assurance mechanisms of collaborative robotic systems in manufacturing," *Robotics and Computer-Integrated Manufacturing*, vol. 67, p. 102022, 2021, doi: 10.1016/j.rcim.2020.102022.
- [23] Anonymous. "Tire Terminology." *Tireworks*. [Online]. Available: <https://tireworks.net/resources/tire-terminology/> [Accessed: May 15, 2023].
- [24] P. Barosz, G. Gołda, and A. Kampa, "Efficiency Analysis of Manufacturing Line with Industrial Robots and Human Operators," *Applied Sciences*, vol. 10, no. 8, p. 2862, 2020, doi: 10.3390/app10082862.
- [25] M. Vido, G. Scur, A. A. Massote, and F. Lima, "The impact of the collaborative robot on competitive priorities: case study of an automotive supplier," *Gest. Prod.*, vol. 27, p. e5358, 2020, doi: 10.1590/0104-530X5358-20.
- [26] H. Taherdoost and M. Madanchian, "Multi-Criteria Decision Making (MCDM) Methods and Concepts," *Encyclopedia*, vol. 3, no. 1, pp. 77-87, 2023, doi: 10.3390/encyclopedia3010006.
- [27] J. Chai, J. N. K. Liu, and E. W. T. Ngai, "Application of decision-making techniques in supplier selection: A systematic review of literature," *Expert Systems with Applications*, vol. 40, no. 10, pp. 3872-3885, 2013, doi: 10.1016/j.eswa.2012.12.040.
- [28] Y. Liu, C. M. Eckert, and C. Earl, "A review of fuzzy AHP methods for decision-making with subjective judgements," *Expert Systems with Applications*, vol. 161, p. 113738, 2020, doi: 10.1016/j.eswa.2020.113738.
- [29] M. Aruldoss, T. M. Lakshmi, and V. P. Venkatesan, "A Survey on Multi Criteria Decision Making Methods and Its Applications," *American Journal of Information Systems*, vol. 1, no. 1, pp. 31-43, 2013, doi: 10.12691/ajis-1-1-5.
- [30] E. Broniewicz and K. Ogrodnik, "A Comparative Evaluation of Multi-Criteria Analysis Methods for Sustainable Transport," *Energies*, vol. 14, no. 16, p. 5100, 2021, doi: 10.3390/en14165100.
- [31] K. A. Souhli and A. En-nadi, "Adoption of GSCM Practices and Sensitivity/influencing Factors: An Empirical Study at the Moroccan Firm Level," *International Journal of Industrial Engineering and Management*, vol. 14, no. 3, pp. 214-231, 2023.
- [32] A. G. Abdullah, M. A. Shafii, S. Pramuditya, T. Setiadiyura, and K. Anzhar, "Multi-criteria decision making for nuclear power plant selection using fuzzy AHP: Evidence from Indonesia," *Energy and AI*, vol. 14, p. 100263, 2023, doi: 10.1016/j.egyai.2023.100263.
- [33] J. J. Buckley, "Fuzzy hierarchical analysis," *Fuzzy Sets and Systems*, vol. 17, no. 3, pp. 233-247, 1985, doi: 10.1016/0165-0114(85)90090-9.
- [34] P. Jaskowski, S. Biruk, and R. Bucon, "Assessing contractor selection criteria weights with fuzzy AHP method application in group decision environment," *Automation in Construction*, vol. 19, no. 2, pp. 120-126, 2010, doi: 10.1016/j.autcon.2009.12.014.
- [35] T. Saaty, "Decision making with the Analytic Hierarchy Process," *Int. J. Services Sciences Int. J. Services Sciences*, vol. 1, pp. 83-98, 2008, doi: 10.1504/IJSSCI.2008.017590.
- [36] A. Ishizaka and A. Labib, "Review of the main developments in the analytic hierarchy process," *Expert Systems with Applications*, vol. 38, no. 11, pp. 14336-14345, 2011, doi: 10.1016/j.eswa.2011.04.143.
- [37] J. M. Hummel, J. F. P. Bridges, and M. J. Ijzerman, "Group Decision Making with the Analytic Hierarchy Process in Benefit-Risk Assessment: A Tutorial," *Patient*, vol. 7, no. 2, pp. 129-140, 2014, doi: 10.1007/s40271-014-0050-7.
- [38] J. Moon and C. Kang, "Application of fuzzy decision making method to the evaluation of spent fuel storage options," *Progress in Nuclear Energy - PROG NUCL ENERGY*, vol. 39, pp. 345-351, 2001, doi: 10.1016/S0149-1970(01)00019-1.
- [39] S.-J. Chen and C.-L. Hwang, "Fuzzy Multiple Attribute Decision Making Methods," in *Fuzzy Multiple Attribute Decision Making. Lecture Notes in Economics and Mathematical Systems*, Berlin, Heidelberg: Springer, 1992, pp. 289-486. doi: 10.1007/978-3-642-46768-4\_5.
- [40] A. Silva, A. C. Simoes, and R. Blanc, "Criteria to consider in a decision model for collaborative robot (cobot) adoption: A literature review," in *IEEE International Conference on Industrial Informatics (INDIN)*, 2022, pp. 477-482. doi: 10.1109/INDIN51773.2022.9976113.
- [41] S. S. Mecheri and C. M. Greene, "Collaborative robot selection using analytical hierarchical process," *International Journal of Rapid Manufacturing*, vol. 8, no. 4, pp. 326-344, 2019, doi: 10.1504/IJRAPIDM.2019.102560.