International Journal of Industrial Engineering and Management

Learning Equitable and Efficient Shift Rosters with Multi-Objective Deep Reinforcement Learning and Counterfactual Fairness Constraints in Operations

B. Thanh Khoa[a,*] 0000-0002-9878-2164, K. Makharov[b] 0000-0002-9341-4602,
B. Samandarov[c] 0000-0002-8296-0894, S. Jafarov[d] 0000-0003-4344-8350,
D. Raupov[e,f] 0000-0002-3336-0884, O. Djurabaev[g] 0000-0002-2801-6069

[a] *Industrial University of Ho Chi Minh City, Vietnam;*
[b] *Kimyo International University in Tashkent, Tashkent, Uzbekistan;*
[c] *Mamun University, Khiva, Uzbekistan;*
[d] *Urgench State University, Urgench, Uzbekistan;*
[e] *Tashkent State Technical University, Tashkent, Uzbekistan;*
[f] *University of Tashkent for Applied Sciences, Tashkent, Uzbekistan;*
[g] *Tashkent State University of Economics, Tashkent, Uzbekistan*

References

[1] A. E. Schoenbaum and J. Tokazewski, "A continuous pursuit of excellence: Leveraging innovative technology, operations and financial insights to overcome healthcare challenges," Manag. Healthc., vol. 9, no. 4, pp. 320–327, 2025.
[2] J. Schwemmer, C. Günsel, M. Kühn, and T. Schmidt, "Workforce rostering for decentrally controlled production systems: A simulation-based optimization framework using a genetic algorithm," Logist. Res., vol. 16, no. 8, pp. 1–26, 2023, doi: 10.23773/2023_8.
[3] M. O'Connell, J. Barry, I. Hartigan, N. Cornally, and M. M. Saab, "The impact of electronic and self-rostering systems on healthcare organisations and healthcare workers: A mixed-method systematic review," J. Clin. Nurs., vol. 33, pp. 2374–2387, 2024, doi: 10.1111/jocn.17114.
[4] D. Yavmutov and S. Bahranov, "Sustainable development of the regional economy in Uzbekistan," Probl. Solut. Sci. Innov. Res., vol. 1, no. 1, pp. 38–46, 2024.
[5] S. W. Lee, D. Park, H. Jeong, and S. Sherzod, Development of Navoi Free Industrial Economic Zone in Uzbekistan. Korea Development Institute, 2010. [Online]. Available: http://archives.kdischool.ac.kr/bitstream/11125/47656/1/Development%20of%20Navoi%20Free%20Industrial%20Economic%20Zone%20in%20Uzbekistan%20%28English%29.pdf. [Accessed: 30-Nov-2025].
[6] N. Shahina, "The role of Just-In-Time system and digitalization in Uzbekistan's industrial development," Cent. Asian J. Multidiscip. Res. Manag. Stud., vol. 2, no. 6, pp. 143–150, 2025.
[7] G. M. W. Ullah, M. Nehring, M. Kizil, and others, "Environmental, social, and governance considerations in production scheduling optimisation for sublevel stoping mining operations: A review of relevant works and future directions," Min. Metall. Explor., vol. 40, pp. 2167–2182, 2023, doi: 10.1007/s42461-023-00869-0.
[8] E. B. Böðvarsdóttir and T. Stidsen, "A review of multi-objective optimization methods for personnel rostering problems," J. Sched., vol. 29, pp. 1–19, 2026, doi: 10.1007/s10951-025-00845-0.
[9] D. Wang, X. Chen, X. Liu, Y. Li, Z. Piao, and H. Li, "Dynamic tariff adjustment for electric vehicle charging in renewable-rich smart grids: A multi-factor optimization approach to load balancing and cost efficiency," Energies, vol. 18, no. 16, p. 4283, 2025, doi: 10.3390/en18164283.

[10] K. Danach, A. Rammal, I. Moukadem, H. Harb, and A. Nasser, "Advanced optimization in e-commerce logistics: Combining matheuristics with random forests for hub location efficiency," IEEE Access, vol. 13, pp. 55915–55926, 2025, doi: 10.1109/ACCESS.2025.3550560.
[11] W. Zhang, G. Xiao, M. Gen, H. Geng, X. Wang, M. Deng, and G. Zhang, "Enhancing multi-objective evolutionary algorithms with machine learning for scheduling problems: Recent advances and survey," Front. Ind. Eng., vol. 2, article 1337174, 2024, doi: 10.3389/fieng.2024.1337174.
[12] L. Qiao, L. Li, and S. Yu, "Multi-objective optimization for human resource allocation using reinforcement learning and enhanced cuckoo search algorithm," Informatica, vol. 49, no. 19, 2025, doi: 10.31449/inf.v49i19.7753.
[13] B. Chaker, M. H. Ammar, and D. Dhouib, "Multi-objective personnel scheduling problem with multiple qualification and client's satisfaction: Real case," Flex. Serv. Manuf. J., vol. 37, pp. 1276–1334, 2025, doi: 10.1007/s10696-024-09570-w.
[14] X. R. Zhang and J. N. Zhou, "Simulation of AIGC-enhanced congestion management in factory autonomous driving," Int. J. Simul. Model., vol. 24, no. 4, pp. 718–729, 2025, doi: 10.2507/IJSIMM24-4-CO19.
[15] G. Nota, F. D. Nota, A. Toro, and M. Nastasia, "A framework for unsupervised learning and predictive maintenance in Industry 4.0," Int. J. Ind. Eng. Manag., vol. 15, no. 4, pp. 304–319, 2024, doi: 10.24867/IJIEM-2024-4-365.
[16] L. Zhang, Z. Qi, and Y. Shi, "Multi-objective reinforcement learning – concept, approaches and applications," Procedia Comput. Sci., vol. 221, pp. 526–532, 2023, doi: 10.1016/j.procs.2023.08.018.
[17] L. De Schutter and D. De Cremer, "How counterfactual fairness modelling in algorithms can promote ethical decision-making," Int. J. Hum.-Comput. Interact., vol. 40, no. 1, pp. 33–44, 2024, doi: 10.1080/10447318.2023.2247624.
[18] A. Samadi, K. Koufos, K. Debattista, and M. Dianati, "Counterfactual explainer for deep reinforcement learning models using policy distillation," ACM Trans. Intell. Syst. Technol., vol. 16, no. 2, pp. 22-36, 2025, doi: 10.1145/3709146.
[19] R. Kapoor, S. Mittal, A. C. Kumari, and K. Srinivas, "Advancing sustainable agricultural development and food security through machine learning: A comparative analysis of crop yield prediction models in Indian agriculture," J. Eng. Manag. Ind. Technol., vol. 3, no. 2, pp. 113–120, 2025, doi: 10.61552/JEMIT.2025.02.005.
[20] A. Vital-Soto, M. F. Baki, and A. Azab, "A multi-objective mathematical model and evolutionary algorithm for the dual-resource flexible job-shop scheduling problem with sequencing flexibility," Flex. Serv. Manuf. J., vol. 35, pp. 626–668, 2023, doi: 10.1007/s10696-022-09446-x.
[21] H. Zhang, Y. Ge, X. Zhao and J. Wang, "Hierarchical deep reinforcement learning for multi-objective integrated circuit physical layout optimization with congestion-aware reward shaping," IEEE Access, vol. 13, pp. 162533–162551, 2025, doi: 10.1109/ACCESS.2025.3610615.
[22] A. R. M. Jamil and N. Nower, "Dynamic weight-based multi-objective reward architecture for adaptive traffic signal control system," Int. J. ITS Res., vol. 20, pp. 495–507, 2022, doi: 10.1007/s13177-022-00305-5.
[23] N. Nigar, M. K. Shahzad, S. Islam, O. Oki, and J. M. Lukose, "A novel multi-objective evolutionary algorithm to address turnover in the software project scheduling problem based on best fit skills criterion," IEEE Access, vol. 11, pp. 89742–89756, 2023, doi: 10.1109/ACCESS.2023.3306838.
[24] X. Ran, W. P. Tay, and C. Lee, "High-performance optimization model based on novel conditional value at risk metric for power grids with high wind power penetration," IEEE Trans. Ind. Informat., vol. 21, no. 7, pp. 5689–5700, Jul. 2025, doi: 10.1109/TII.2025.3556085.
[25] Q. Lai, G. Liu, B. Zhang, and K. Zhang, "Simulating confidence intervals for conditional value-at-risk via least-squares metamodels," INFORMS J. Comput., vol. 37, no. 4, pp. 1087–1105, 2025, doi: 10.1287/ijoc.2023.0394.
[26] H. Ghanbari, S. Tavakoli, M. Shabani, E. Mohammadi, S. J. Sadjadi, and R. R. Kumar, "A two-stage framework for enhancing cryptocurrency portfolio performance: Integrating credibilistic CVaR criterion with a novel asset preselection approach," PLoS One, vol. 20, no. 7, e0325973, 2025, doi: 10.1371/journal.pone.0325973.
[27] X. Wu, H. Zhang, H. Chen, S. Wang, and L. Gong, "Combustion optimization study of pulverized coal boiler based on proximal policy optimization algorithm," Appl. Therm. Eng., vol. 254, 123857, 2024, doi: 10.1016/j.applthermaleng.2024.123857.
[28] Y. Gu, Y. Cheng, C. L. P. Chen, and X. Wang, "Proximal policy optimization with policy feedback," IEEE Trans. Syst., Man, Cybern., Syst., vol. 52, no. 7, pp. 4600–4610, 2022, doi: 10.1109/TSMC.2021.3098451.
[29] A. Boudlal, A. Khafaji, and J. Elabbadi, "Entropy adjustment by interpolation for exploration in proximal policy optimization (PPO)," Eng. Appl. Artif. Intell., vol. 133, no. E, 108401, 2024, doi: 10.1016/j.engappai.2024.108401.
[30] H. Wu and H. Chen, "Multi-site wind speed prediction based on graph embedding and cyclic graph isomorphism network (GIN-GRU)," Energies, vol. 17, no. 14, 3516, 2024, doi: 10.3390/en17143516.
[31] C. Yang, Y. Xia, Z. Chu, and X. Zha, "Logic synthesis optimization sequence tuning using RL-based LSTM and graph isomorphism network," IEEE Trans. Circuits Syst. II, Exp. Briefs, vol. 69, no. 8, pp. 3600–3604, 2022, doi: 10.1109/TCSII.2022.3168344.
[32] S. Shaik, J. M. Smereka, and Y. Wang, "Generalized advantage estimation for distributional policy gradients," in Proc. Amer. Control Conf. (ACC), Denver, CO, USA, 2025, pp. 3073–3078, doi: 10.23919/ACC63710.2025.11107721.
[33] E. Jacinto, F. Martinez, and F. Martinez, "Navigation of autonomous vehicles using reinforcement learning with generalized advantage estimation," Int. J. Adv. Comput. Sci. Appl. (IJACSA), vol. 14, no. 1, pp. 954-959, 2023, doi: 10.14569/IJACSA.2023.01401103.
[34] M. Buyl and T. De Bie, "The KL-divergence between a graph model and its fair I-projection as a fairness regularizer," in Mach. Learn. Knowl. Discov. Databases, Res. Track, ECML PKDD 2021, Lecture Notes in Computer Science, vol. 12976, Springer, Cham, 2021, pp. 351–366, doi: 10.1007/978-3-030-86520-7_22.
[35] K. M. Tekale and N. Rahul, "AI bias mitigation in insurance pricing and claims decisions," Int. J. Artif. Intell. Data Sci. Mach. Learn., vol. 5, no. 1, pp. 138–148, 2024, doi: 10.63282/3050-9262.IJAIDSML-V5I1P113.
[36] J. A. Henderson, "Reducing adverse impact while maintaining validity: Finding the balance between competing employee selection goals," Ph.D. dissertation, Univ. Tennessee, Knoxville, TN, USA, 2004.