A Simheuristic Approach to Optimize Energy Consumption in the Single-Machine Scheduling Problem with Stochastic Processing Times

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Abstract

This paper addresses a stochastic single-machine scheduling problem with energy consumption. In this problem, job processing times are random variables, and total energy consumption depends on job scheduling, as each job has its own energy use and each period follows a Time-Of-Use tariff policy. To solve the problem, we propose a simheuristic algorithm that combines the metaheuristics Simulated Annealing and Greedy Randomized Adaptive Search Procedure to explore the solution space, along with Monte Carlo Simulation to better evaluate the solutions during the search. The solutions obtained are compared with those derived from a deterministic approach, and the results show that the simheuristic outperforms the deterministic method in terms of Average, Value at Risk, and Conditional Value at Risk, emphasizing the importance of incorporating uncertainty into the solution methods.

Keywords: Green Scheduling, Time-Of-use, Stochastic Processing Time.

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1. Literature review

This document presents all the articles used in the three literature reviews conducted in the paper "Simheuristic Approach to the Single-Machine Scheduling Problem with Stochastic Processing Times and Energy-Efficient". This section aims to establish the review protocols, which specify the objectives, the questions to be answered, the databases to be consulted, the types of studies to be analyzed, the keywords to be searched, the languages, the years of publication, and the inclusion and exclusion criteria for the studies obtained. Thus, these protocols seek to provide a clear and pre-defined framework that outlines and guides the entire review process, describing in a transparent manner all the methodological aspects for the search and selection of articles, thereby ensuring the reproducibility of the study.

Therefore, we have three objectives, one for each review. For SSMSP, we aim to identify gaps and trends regarding this model. For SMGSP, to evaluate the state of the art. And for SGSP, to analyze the current landscape of research on this topic. The questions to be answered for each objective are presented in Table 1.

Table 1: Questions to be answered for each review

Review	Questions
SSMSP	(1) Which methods are used to solve this type of problem; (2) What are the most addressed stochastic parameters in the literature.
SMGSP	(1) Classification of models according to the number of objective functions; (2) Which objective function(s) is/are considered; (3) What are the main environmental considerations; (4) What methods are used to solve this type of problem.
SGSP	(1) Which methods are used to solve this type of problem; (2) What are the most addressed stochastic parameters in the literature; (3) What are the main environmental considerations.

The review was conducted exclusively using the Web of Science database as the source for the literature review. This choice was made because this database is recognized for its multidisciplinary scope and its extensive coverage of renowned international scientific journals. Additionally, the search was

limited to only one type of document, which is articles, as they represent a primary and consolidated source of academic knowledge, typically subjected to a rigorous peer-review process, which ensures the credibility and reliability of the information contained in them.

Preliminarily, a search was conducted on Google Scholar to identify keywords present in existing works in the literature. This enabled the formulation of a search string that ensured both the breadth and accuracy of the review, aiming to avoid the exclusion of relevant studies and the inclusion of irrelevant ones. Furthermore, all searches for keywords were performed only in the titles (TI) and the abstract (AB) of the works, and the asterisk (" * ") was used as a truncation operator to find all research with the same root. Thus, the search strings adopted can be observed in Table 2.

Table 2: Search string adopted for each review

Review	Search string
SSMSP	TI=(*single machine*) AND TI=(*sched**) AND (TI=(*simheuristic*) OR TI=(*stoch**) OR TI=(*uncert**)) AND (AB=(*heuristi**) OR TI=(*simheuris**) OR TI=(*optimiz**))
SMGSP	TI=(*single machine*) AND TI=(*sched**) AND (TI=(*green*) OR TI=(*sustainab**) OR TI=(*energ**) OR TI=(*carbon**) OR TI=(*nois**) OR TI=(*pollut**) OR TI=(*tariff**) OR TI=(*Time Of Use*) OR TI=(*Energy-effici**)OR TI=(*Electricity prices**))
SGSP	TI=(*sched**) AND (TI=(*green*) OR TI=(*sustainab**) OR TI=(*energ**) OR TI=(*carbon**) OR TI=(*nois**) OR TI=(*pollut**)) AND (TI=(*simheuristic*) OR TI=(*stoch**) OR TI=(*uncert**)) AND (TI=(*single machine*) OR TI=(*parallel machines*) OR TI=(*flow shop*) OR TI=(*flow-shop*) OR TI=(*flowshop*) OR TI=(*jop shop*) OR TI=(*jop-shop*) OR TI=(*jopshop*) OR TI=(*open shop*) OR TI=(*open-shop*) OR TI=(*openshop*))

Therefore, as presented in Table 2, for the SSMSP review, the terms "simheuristic", "stoch*", "uncert*" were used to search for works that deal with random variables, and the terms "heuristi*", "simheuris*", and "optimiz*" were used to filter only approaches that use optimization methods. This search returned 19 results.

Similarly, for the SMGSP review, the terms "green", "sustainab*", "energ*", "carbon*", "nois*", "pollut*", "tariff*", "Time of use", and "Energy-

effici*" were adopted as filters to search for only works that have environmental considerations in their scope. The term "single machine*" was used to delimit the manufacturing environment, and the term "sched*" was adopted to specify the addressed problem. By using this search string, 40 works were retrieved.

For the SGSP review, where the terms "single machine", "parallel machine", "flow shop", "job shop", "open shop", and their variants are adopted to represent all the manufacturing environments existing in the sequencing literature. This search returned 8 results. All searches and article counting for each review were conducted on 05/03/2025.

The search was conducted without any time limitations or document publication type restrictions (i.e., conferences, symposia, and journals). All works were read in full, with only those that did not address the scheduling topic or were not fully available being excluded.

The tables provide a structured summary of the key aspects analyzed in the reviewed articles, offering a comprehensive overview of the state of the art in these areas. This mapping enables the identification of emerging trends and research gaps, providing insights for the development of new approaches and contributing to advancements in the field.

Table 3: Articles used for the SSMSP review

Ref.	Year	Objective Function	Stochastic parameter	Solution approach
[1]	1988	Inventory costs and setup cost	Demands	Heuristics with Simulation
[2]	1988	Inventory costs and setup cost	Demands	Heuristics with Simulation
[3]	1992	Reward	Release date	Heuristics with Simulation
[4]	1994	Inventory costs and setup cost	Demands	Heuristics with Simulation
[5]	1994	Earliness and tardiness costs	Processing times	Heuristics with Simulation
[6]	1997	Total tardiness	Processing times	Robust Programming
[7]	2002	Total tardiness	Processing times and due dates	Heuristics with Simulation
[8]	2007	Weighted total tardiness	Processing times and due dates	Heuristics with Simulation
[9]	2007	Net present value	Reward value	Branch-and-Bound
[10]	2009	Weighted total tardiness	Machine breakdown	Heuristics with Simulation
[11]	2013	Weighted total tardiness	Processing times	Heuristics with Simulation
[12]	2013	Makespan and Total completion time	Processing times	Branch-and-Bound
[13]	2014	Sum of completion times	Processing times	Robust Programming
[14]	2019	Total tardiness	Setups	Stochastic Programming
[15]	2018	Maximum tardiness	Release date	Robust Programming
[16]	2020	Maximum waiting time	Processing times	Robust Programming
[17]	2020	Makespan	Machine breakdown	Simheuristics
[18]	2022	Makespan	Processing times	Robust Programming
[19]	2024	Earliness and tardiness costs	Machine breakdown	Machine Learning

Table 4: Articles used for the SMGSP review

Ref.	Year	Objective Function	Environmental Characteristic	Solution approach
[20]	2014	Makespan and TEC	TOU	Exact Method
[21]	2014	TEC	Machine states and TOU	Metaheuristic
[22]	2015	Maximum tardiness and TEC	Speed adjustment	Exact Method
[23]	2016	TEC	TOU and Speed adjustment	Exact Method
[24]	2016	Makespan and TEC	TOU	Exact Method
[25]	2016	TEC	TOU	Exact Method
[26]	2016	Makespan and TEC	TOU	Heuristic
[27]	2016	TEC	TOU	Heuristic
[28]	2016	Total tardiness and TEC	Setups	Exact Method
[29]	2017	Maximum tardiness and TEC	Machine states	Exact Method
[30]	2017	Total earliness and TEC	Machine states and TOU	Exact Method and Heuristic
[31]	2017	TEC	Machine reliability	Exact Method and Metaheuristic
[32]	2017	Weighted total tardiness	Speed adjustment	Metaheuristic
[33]	2017	Makespan and TEC	Machine states and TOU	Heuristic
[34]	2018	Total flow time and CO_2 emission	CO_2 emission	Metaheuristic
[35]	2018	Total tardiness and TEC	TOU	Metaheuristic
[36]	2018	Makespan and TEC	TOU	Exact Method and Heuristic
[37]	2019	Weighted earliness/tardiness and TEC	TOU	Metaheuristic
[38]	2019	Total tardiness and TEC	Machine reliability	Metaheuristic
[39]	2019	TEC	Machine states and TOU	Exact Method
[40]	2019	TEC	Machine states and TOU	Exact Method
[41]	2019	Total tardiness and TEC	Machine states	Metaheuristic
[42]	2019	TEC	TOU	Exact Method
[43]	2019	Makespan and TEC	TOU	Metaheuristic
[44]	2019	Total tardiness and TEC	Energy storage	Machine Learning
[45]	2020	TEC	Machine states and TOU	Metaheuristic
[46]	2020	Makespan and TEC	TOU	Metaheuristic
[47]	2020	Weighted total tardiness and TEC	TOU	Metaheuristic
[48]	2021	Total tardiness and TEC	Speed adjustment	Metaheuristic
[49]	2021	Weighted cost and TEC	Machine reliability	Simulated Annealing
[50]	2021	TEC and Production cost	TOU	Heuristic
[51]	2022	TEC	TOU and Speed adjustment	Metaheuristic
[52]	2022	Makespan and TEC	Energy storage	Metaheuristic
[53]	2022	Total tardiness and TEC	Setups	Metaheuristic
[54]	2022	Tardiness and Noise pollution	Noise	Metaheuristic Algorithm
[55]	2022	Total tardiness and TEC	Machine states	Metaheuristic
[56]	2022	Total tardiness and TEC	TOU	Metaheuristic
[57]	2023	Makespan and TEC	TOU	Metaheuristic
[58]	2023	Cost	Machine states and Speed adjustment	Exact Method and Heuristic
[59]	2024	TEC	TOU	Exact Method

Table 5: Articles used for the SGSP review

Ref.	Year	Objective Function	Stochastic parameter	Environmental Characteristic	Manuf. Env.	Solution approach
[60]	2016	CO_2 emission and Makespan	Amplitude and magnitude of energy	Sustainable energy storage	1	Interval number theory
[61]	2019	Makespan and TEC	Processing time	Speed adjustment	F	Heuristic
[62]	2020	Makespan and TEC	Processing time	Speed adjustment	F	Metaheuristics
[63]	2020	Makespan and TEC	Processing time	Sustainable energy storage	F	Heuristic
[64]	2021	TEC	Arrival and cancellation of orders	TOU	F	Metaheuristics
[65]	2023	Makespan and TEC	Processing time	Speed adjustment	Pm	Heuristic
[66]	2023	Profit	Processing time	CO_2 emission	1	Machine learning
[67]	2024	TEC	Amplitude and magnitude of renewable energy	TOU and Renewable energy	F	Stochastic Programming
[68]	2024	Minimize total delay and TEC	Processing time	Machine states	O	Heuristic

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References

[1] R. C. Leachman, A. Gascon, A heuristic scheduling policy for multi-item, single-machine production systems with time-varying, stochastic demands, Management Science 34 (1988) 377–390.

[2] A. Gascon, The lookahead heuristic for multi-item single machine production scheduling with dynamic, stochastic demands, INFOR: Information Systems and Operational Research 26 (1988) 114–126.

[3] N. Fay, K. D. Glazebrook, On a "no arrivals" heuristic for single machine stochastic scheduling, Operations research 40 (1992) 168–177.

[4] A. Gascon, R. C. Leachman, P. Lefrançois, Multi-item, single-machine scheduling problem with stochastic demands: a comparison of heuristics, THE INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH 32 (1994) 583–596.

[5] H. Soroush, L. Fredendall, The stochastic single machine scheduling problem with earliness and tardiness costs, European Journal of Operational Research 77 (1994) 287–302.

[6] R. L. Daniels, J. E. Carrillo, β-robust scheduling for single-machine systems with uncertain processing times, IIE transactions 29 (1997) 977–985.

[7] W. Jang, Dynamic scheduling of stochastic jobs on a single machine, European Journal of Operational Research 138 (2002) 518–530.

[8] H. M. Soroush, Minimizing the weighted number of early and tardy jobs in a stochastic single machine scheduling problem, European Journal of Operational Research 181 (2007) 266–287.

[9] J. G. Szmerekovsky, Single machine scheduling under market uncertainty, European journal of operational research 177 (2007) 163–175.

[10] Q. Li, B. Wang, A stable scheduling for single machine under uncertainty, in: 2009 IEEE International Conference on Automation and Logistics, IEEE, 2009, pp. 526–531.

[11] H. Soroush, Scheduling stochastic jobs on a single machine to minimize weighted number of tardy jobs, Kuwait Journal of Science 40 (2013).

[12] H. Soroush, F. Amin, Scheduling in stochastic bicriteria single machine systems with job-dependent learning effects, Kuwait Journal of Science 40 (2013).

[13] C.-C. Lu, K.-C. Ying, S.-W. Lin, Robust single machine scheduling for minimizing total flow time in the presence of uncertain processing times, Computers & Industrial Engineering 74 (2014) 102–110.

[14] M. Ertem, F. Ozcelik, T. Saraç, Single machine scheduling problem with stochastic sequence-dependent setup times, International Journal of Production Research 57 (2019) 3273–3289.

[15] F. Yue, S. Song, Y. Zhang, J. N. Gupta, R. Chiong, Robust single machine scheduling with uncertain release times for minimising the maximum waiting time, International Journal of Production Research 56 (2018) 5576–5592.

[16] F. Yue, S. Song, P. Jia, G. Wu, H. Zhao, Robust single machine scheduling problem with uncertain job due dates for industrial mass production, Journal of Systems Engineering and Electronics 31 (2020) 350–358.

[17] N. N. A. Halim, S. S. R. Shariff, S. M. Zahari, Single-machine integrated production preventive maintenance scheduling: A simheuristic approach, MATEMATIKA: Malaysian Journal of Industrial and Applied Mathematics (2020) 113–126.

[18] M. Bold, M. Goerigk, Investigating the recoverable robust single machine scheduling problem under interval uncertainty, Discrete Applied Mathematics 313 (2022) 99–114.

[19] A. Sabri, H. Allaoui, O. Souissi, Reinforcement learning and stochastic dynamic programming for jointly scheduling jobs and preventive maintenance on a single machine to minimise earliness-tardiness, International Journal of Production Research 62 (2024) 705–719.

[20] J. Cheng, F. Chu, W. Xia, J. Ding, X. Ling, Bi-objective optimization for single-machine batch scheduling considering energy cost, in: 2014 international conference on control, decision and information technologies (CoDIT), IEEE, 2014, pp. 236–241.

[21] F. Shrouf, J. Ordieres-Meré, A. García-Sánchez, M. Ortega-Mier, Optimizing the production scheduling of a single machine to minimize total energy consumption costs, Journal of Cleaner Production 67 (2014) 197–207.

[22] A. Che, K. Lv, E. Levner, V. Kats, Energy consumption minimization for single machine scheduling with bounded maximum tardiness, in: 2015 IEEE 12th international conference on networking, sensing and control, IEEE, 2015, pp. 146–150.

[23] K. Fang, N. A. Uhan, F. Zhao, J. W. Sutherland, Scheduling on a single machine under time-of-use electricity tariffs, Annals of Operations Research 238 (2016) 199–227.

[24] J. Cheng, F. Chu, C. Chu, W. Xia, Bi-objective optimization of single-machine batch scheduling under time-of-use electricity prices, RAIRO-Operations Research-Recherche Opérationnelle 50 (2016) 715–732.

[25] J. Cheng, F. Chu, M. Liu, W. Xia, Single-machine batch scheduling under time-of-use tariffs: New mixed-integer programming approaches, in: 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC), IEEE, 2016, pp. 003498–003503.

[26] S. Wang, M. Liu, F. Chu, C. Chu, Bi-objective optimization of a single machine batch scheduling problem with energy cost consideration, Journal of cleaner production 137 (2016) 1205–1215.

[27] A. Che, Y. Zeng, K. Lyu, An efficient greedy insertion heuristic for energy-conscious single machine scheduling problem under time-of-use electricity tariffs, Journal of Cleaner Production 129 (2016) 565–577.

[28] Y.-C. Choi, Dispatching rule-based scheduling algorithms in a single machine with sequence-dependent setup times and energy requirements, Procedia CIRP 41 (2016) 135–140.

[29] A. Che, X. Wu, J. Peng, P. Yan, Energy-efficient bi-objective single-machine scheduling with power-down mechanism, Computers & Operations Research 85 (2017) 172–183. URL: https://www.sciencedirect.com/science/article/pii/S0305054817300953. doi:https://doi.org/10.1016/j.cor.2017.04.004.

[30] S. Lee, B. Do Chung, H. W. Jeon, J. Chang, A dynamic control approach for energy-efficient production scheduling on a single machine under time-varying electricity pricing, Journal of Cleaner Production 165 (2017) 552–563.

[31] M. Abedi, R. Chiong, N. Noman, R. Zhang, A hybrid particle swarm optimisation approach for energy-efficient single machine scheduling with cumulative deterioration and multiple maintenances, in: 2017 IEEE Symposium Series on Computational Intelligence (SSCI), IEEE, 2017, pp. 1–8.

[32] X. Liao, R. Zhang, R. Chiong, Multi-objective optimization of single machine scheduling with energy consumption constraints, in: 2017 IEEE Symposium Series on Computational Intelligence (SSCI), IEEE, 2017, pp. 1–8.

[33] J. Cheng, F. Chu, M. Liu, P. Wu, W. Xia, Bi-criteria single-machine batch scheduling with machine on/off switching under time-of-use tariffs, Computers & Industrial Engineering 112 (2017) 721–734.

[34] H.-L. Zhang, B. Qian, Z.-X. Sun, R. Hu, B. Liu, N. Guo, Single-machine green scheduling to minimize total flow time and carbon emission, in: Intelligent Computing Theories and Application: 14th International Conference, ICIC 2018, Wuhan, China, August 15-18, 2018, Proceedings, Part I 14, Springer, 2018, pp. 670–678.

[35] S. Rubaiee, S. Cinar, M. B. Yildirim, An energy-aware multiobjective optimization framework to minimize total tardiness and energy cost on a single-machine nonpreemptive scheduling, IEEE Transactions on Engineering Management 66 (2018) 699–714.

[36] S. Zhang, A. Che, X. Wu, C. Chu, Improved mixed-integer linear programming model and heuristics for bi-objective single-machine batch scheduling with energy cost consideration, Engineering optimization 50 (2018) 1380–1394.

[37] Y. Liu, X. Liao, R. Zhang, An enhanced mopso algorithm for energy-efficient single-machine production scheduling, Sustainability 11 (2019) 5381.

[38] L. Chen, J. Wang, X. Xu, An energy-efficient single machine scheduling problem with machine reliability constraints, Computers & Industrial Engineering 137 (2019) 106072.

[39] M. Aghelinejad, Y. Ouazene, A. Yalaoui, Complexity analysis of energy-efficient single machine scheduling problems, Operations Research Perspectives 6 (2019) 100105.

[40] M. M. Aghelinejad, Y. Ouazene, A. Yalaoui, Single-machine scheduling problem with total energy consumption costs minimization, IFAC-PapersOnLine 52 (2019) 409–414.

[41] J. Wang, M. Qian, L. Hu, S. Li, Q. Chang, Energy saving scheduling of a single machine system based on bi-objective particle swarm optimization, in: 2019 IEEE 15th International Conference on Automation Science and Engineering (CASE), IEEE, 2019, pp. 585–589.

[42] S.-H. Chen, Y.-C. Liou, Y.-H. Chen, K.-C. Wang, Order acceptance and scheduling problem with carbon emission reduction and electricity tariffs on a single machine, Sustainability 11 (2019) 5432.

[43] S. Rubaiee, M. B. Yildirim, An energy-aware multiobjective ant colony algorithm to minimize total completion time and energy cost on a single-machine preemptive scheduling, Computers & Industrial Engineering 127 (2019) 240–252.

[44] T. Buechler, F. Pagel, T. Petitjean, M. Draz, S. Albayrak, Optimal energy supply scheduling for a single household: Integrating machine learning for power forecasting, in: 2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe), IEEE, 2019, pp. 1–5.

[45] Y.-C. Tsao, V.-V. Thanh, F.-J. Hwang, Energy-efficient single-machine scheduling problem with controllable job processing times under differential electricity pricing, Resources, Conservation and Recycling 161 (2020) 104902.

[46] S. Zhou, M. Jin, N. Du, Energy-efficient scheduling of a single batch processing machine with dynamic job arrival times, Energy 209 (2020) 118420.

[47] Q. Jiang, X. Liao, R. Zhang, Q. Lin, Energy-saving production scheduling in a single-machine manufacturing system by improved particle swarm optimization, Mathematical Problems in Engineering 2020 (2020) 1–16.

[48] G. Bektur, A hybrid heuristic solution based on simulated annealing algorithm for energy efficient single machine scheduling problem with sequence dependent setup times (2021).

[49] M. Salama, S. Srinivas, Adaptive neighborhood simulated annealing for sustainability-oriented single machine scheduling with deterioration effect, Applied Soft Computing 110 (2021) 107632.

[50] P. Wu, J. Cheng, F. Chu, Large-scale energy-conscious bi-objective single-machine batch scheduling under time-of-use electricity tariffs via effective iterative heuristics, Annals of Operations Research 296 (2021) 471–494.

[51] Y. An, C. Li, X. Chen, Y. Li, Z. Zhao, H. Cao, An optimal energy-efficient scheduling with processing speed selection and due date constraint in a single-machine environment, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture (2022).

[52] H.-J. Kim, E.-S. Kim, J.-H. Lee, L. Tang, Y. Yang, Single-machine scheduling with energy generation and storage systems, International Journal of Production Research 60 (2022) 7033–7052.

[53] D. Qiao, Y. Wang, J. Pei, W. Bai, X. Wen, Research on green single machine scheduling based on improved ant colony algorithm, Measurement and Control 55 (2022) 35–48.

[54] J. Jia, C. Lu, L. Yin, Energy saving in single-machine scheduling management: An improved multi-objective model based on discrete artificial bee colony algorithm, Symmetry 14 (2022) 561.

[55] E. Tarakçi, A. H. Zaim, O. Öztaş, Energy-based scheduling optimization to minimize the total energy consumption and the total tardiness in a single machine manufacturing system with the sequence-dependent setup times, Politeknik Dergisi 27 (2022) 169–183.

[56] D. S. Schorn, L. Mönch, Learning dispatching rules for energy-aware scheduling of jobs on a single batch processing machine, in: 2022 Winter Simulation Conference (WSC), IEEE, 2022, pp. 3360–3371.

[57] P. Wu, N. Li, J. Cheng, C. Chu, Energy-efficient single-machine scheduling with release dates under time-of-use electricity tariffs, Journal of Cleaner Production 393 (2023) 136228. URL: https://www.sciencedirect.com/science/article/pii/S0959652623003864. doi:https://doi.org/10.1016/j.jclepro.2023.136228.

[58] A. Roshani, M. Paolucci, D. Giglio, M. Demartini, F. Tonelli, M. A. Dulebenets, The capacitated lot-sizing and energy efficient single machine scheduling problem with sequence dependent setup times and costs in a closed-loop supply chain network, Annals of operations research 321 (2023) 469–505.

[59] Z. Tian, L. Zheng, Single machine parallel-batch scheduling under time-of-use electricity prices: New formulations and optimisation approaches, European Journal of Operational Research 312 (2024) 512–524.

[60] C.-H. Liu, Mathematical programming formulations for single-machine scheduling problems while considering renewable energy uncertainty, International Journal of Production Research 54 (2016) 1122–1133.

[61] Y. Fu, G. Tian, A. M. Fathollahi-Fard, A. Ahmadi, C. Zhang, Stochastic multi-objective modelling and optimization of an energy-conscious distributed permutation flow shop scheduling problem with the total tardiness constraint, Journal of cleaner production 226 (2019) 515–525.

[62] M. F. Amiri, J. Behnamian, Multi-objective green flowshop scheduling problem under uncertainty: Estimation of distribution algorithm, Journal of Cleaner Production 251 (2020) 119734.

[63] S. Wang, S. J. Mason, H. Gangammanavar, Stochastic optimization for flow-shop scheduling with on-site renewable energy generation using a case in the united states, Computers & Industrial Engineering 149 (2020) 106812.

[64] M. K. Marichelvam, M. Geetha, A memetic algorithm to solve uncertain energy-efficient flow shop scheduling problems, The International Journal of Advanced Manufacturing Technology 115 (2021) 515–530.

[65] L. Wang, Y. Qi, Scheduling an energy-aware parallel machine system with deteriorating and learning effects considering multiple optimization objectives and stochastic processing time, CMES-Computer Modeling in Engineering & Sciences 135 (2023) 325–339.

[66] F. Zheng, Z. Wang, Y. Xu, M. Liu, Single machine scheduling with uncertain processing times and carbon emission constraint in the shared manufacturing environment, Annals of Operations Research (2023) 1–31.

[67] M. Ghorbanzadeh, M. Davari, M. Ranjbar, Energy-aware flow shop scheduling with uncertain renewable energy, Computers & Operations Research 170 (2024) 106741.

[68] Y. Fu, M. Zhou, X. Guo, L. Qi, K. Gao, A. Albeshri, Multiobjective scheduling of energy-efficient stochastic hybrid open shop with brain storm optimization and simulation evaluation, IEEE Transactions on Systems, Man, and Cybernetics: Systems (2024).