Pak. j. life soc. Sci. (2026), 24(1): 11-19 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2026-24.1.002

RESEARCH ARTICLE

The Cuckoo Optimization Algorithm to Resolve a Multi-Skills Inspectors Scheduling Problem

Kallel Lobna[1]*, Koubaa Mayssa[2], Hbiri Aziz[3]

[1,2,3]University of Sfax, OLID Laboratory, ISGI, Sfax, Tunisia

ARTICLE INFO

Received: Nov 12, 2025

Accepted: Jan 6, 2026

Keywords

Personnel Scheduling
Multi-Skilled Inspectors
Metaheuristics
COA
Performance

***Corresponding Author:**

lobna_kallel@yahoo.fr

ABSTRACT

Personnel scheduling in the technical inspection field belongs to the class of NP-hard problems. This paper addresses a multi-skilled inspectors scheduling problem using the Cuckoo Optimization Algorithm (COA), a population-based metaheuristic that has demonstrated strong performance on similar scheduling problems. The essential objective is to provide an efficient solution approach and to benchmark the results of COA against those obtained with the Greedy randomized adaptive search procedure (GRASP) on a real case study from a technical inspection company in Tunisia. The computational results show that COA yields better schedules and improved solution quality compared to GRASP, in terms of both effectiveness and performance.

1.INTRODUCTION

The term logistics first appeared in the eighteenth century in connection with the emerging problem of supplying armies. It then gradually spread to industry, where it designated handling and transportation operations for goods. Until the 1970s, however, logistics was mainly limited to execution tasks in warehouses and on shipping docks, and it had relatively little importance in most firms, where it was considered a secondary function. Subsequently, logistics came to be understood as an operational link between the different activities of the company, ensuring the reliability and consistency of material flows with the objective of optimizing resources, reducing costs, and improving the quality of service delivered to customers. In the mid-1990s, logistics evolved into a global function managing physical flows between customers and suppliers, and it became a new discipline in the management of industrial, retail, and transport companies.

Today, delivery times, product quality, inventory management, and related aspects are considered key requirements in logistics and quality management. For customers, delivery time is a major factor in the choice of a product and is therefore directly related to the company's quality performance. As a result, logistics managers can no longer neglect product quality in order to guarantee on-time delivery Chaker et al. (2019). Beyond handling and inventory management, logistics now encompasses the management of all physical and informational flows throughout the supply chain, including procurement, production, and distribution. In other words, it involves transversal management that removes traditional boundaries between suppliers and customers, enabling greater transparency and visibility along the chain and ultimately enhancing overall supply chain performance.

Quality control is a technical activity that verifies whether a product conforms to specific limits known by the controller (also called inspector), who performs the inspection and makes the appropriate decision. Depending on the results, the product may be considered compliant, non-compliant and discarded, non-compliant but repairable, or exceptionally accepted despite non-conformities. Quality control is therefore one component of quality management and can be carried out at reception, during production, or at the end of the process, but it does not represent the entire quality system. On the contrary, the need for control is sometimes questioned, since a robust quality system is supposed to prevent anomalies and non-conformities.

In this context, product inspection within the supply chain is part of the overall quality management system of each company. It must be conducted under appropriate conditions, with trained and qualified personnel, in order to generate useful information for corrective or preventive actions and to continuously improve production quality. Inspection is therefore considered an important and essential element of company management. Consequently, the person responsible for carrying out control and inspection tasks must be certified according to specific standards, and must be capable of organizing, preparing, executing, and successfully completing the inspection mission. This person must also possess adequate skills and sound knowledge of inspection techniques and procedures. As a result, inspection missions, particularly in technical fields, are becoming increasingly complex and diverse, and they require well-qualified and well-trained inspectors to perform the various inspections requested by customers Chaker et al. (2019).

The main challenge that arises is the selection and assignment of the most suitable inspector to perform a given task for a client, while considering multiple criteria such as competence, certification, and availability. This constitutes a real problem for inspection companies when planning and assigning inspectors to the different requested missions, especially when the goal is to improve service quality and, consequently, customer satisfaction. Effective planning and allocation of inspection personnel to control tasks can enhance service quality and lead to higher customer satisfaction. However, due to the complexity and multiplicity of factors to be considered when planning and allocating inspection personnel, companies often face customer complaints, which force managers to revise and adjust their allocation plans Chaker et al. (2024).

In our work, we interested on the staff scheduling problem in an industrial context, and more specifically on the assignment of inspectors to inspection missions while accounting for several constraints and stakeholders' objectives. The aim is to increase worker performance, service quality, and productivity, while reducing costs related to overstaffing and improving both profitability and service quality. To achieve this, a decision support system is proposed to solve the scheduling problem encountered in inspection and technical control activities and to provide operationally relevant solutions.

The remainder of this paper is organized as follows. Section 2 presents the personnel scheduling problem in industry together with a brief literature review. Section 3 describes the Cuckoo Optimization Algorithm. Section 4 reports the experimental setup and computational results. Finally, concluding remarks and perspectives are provided in Section 5.

2.Industrial Staff Scheduling problem

The aim of this section is to provide a brief overview of the state of the art on personnel scheduling problems. In this work, the focus is placed on three main sectors: the retail industry, transportation, and the industrial and manufacturing sector. The different research contributions are presented in chronological order within each sector.

In the retail industry, several studies have addressed workforce scheduling problems. Mac Vicar et al. (2017) develop a mathematical model to handle workforce scheduling under contingency situations. The same type of approach is used by Burgy et al. (2019) to deal with employee scheduling under varying demand. Porto et al. (2019) propose a mixed-integer linear programming model to design a hybrid and flexible work plan using real data from a retail company. Henao et al. (2019) study a multi-skilling workforce scheduling problem in a retail store under demand uncertainty, with the objective of reducing total costs in the case of staff shortages; they solve the problem using a mathematical model combined with a sequential heuristic approach. In a similar context, Hassani et al. (2020) develop a heuristic method that allows for rapid rescheduling personnel, and which demonstrate its high effectiveness through computational experiments on large instances.

In the transportation sector, several works have also been presented. Rama et al. (2017) present a linear programming model that deals with driver scheduling in a large metropolis, while providing optimal solutions and revenue savings. Janacek et al. (2017) present a mathematical model that allows for the periodic planning of train crew scheduling, adapted to practical applications among European railway operators. Bowden and Ragsdale (2018) address the problem of truck driver scheduling while ensuring travel time optimization and taking into account driver fatigue; their problem is formulated as a mathematical model. Ciancio et al. (2018) use a simulated annealing technique for the problem of vehicle scheduling and crew planning for large-scale real-world data. Shiau et al. (2020) address the scheduling problem in the aviation field by using a mathematical model for airline staff planning, while considering minimum labor requirements as well as costs.

Finally, for the third sector, the Industry and Manufacturing, Denkena et al. (2017) present a mathematical model based on production data to evaluate the effect of employees on setup and processing time. Wongwien and Nanthavanij (2017) also present a mixed-integer linear programming model for scheduling workers performing hazardous industrial activities, in order to limit the time, they perform these activities to legal limits. Hochdorffer et al. (2018) are interested in short-term personnel planning on the production lines of an automobile manufacturer, using a heuristic approach based on integer linear programming. For Al. Rawi and Mukherjee (2019), they present an Excel Solver-based approach in a construction company for planning and scheduling workers. Chen et al. (2020) propose a solution for project portfolio scheduling and personnel multi-skilling using a multi-objective optimization model. However, among the most recent works, we can notice that Chaker et al. (2024) is the only work that has addressed the technical control and inspection field and that deals in the technical control field the personnel scheduling problem. The essential aim of this work is to develop a decision support system to create schedules that can be used directly, taking into account costs, client preferences, fairness, and many other constraints and stakeholders' objectives. This mathematical model is after applied to a real case study for a technical control company in Tunisia, and a heuristic approach is used to provide a comparison between an exact method and an approximate method.

Since the problem addressed in the work of Chaker et al. (2024) is new and has not been treated in the literature, this research focuses on the same problem, but using the Cuckoo Optimization Algorithm, which has shown its performance in scheduling for several similar problems. For example, Koubaa et al. (2022) demonstrate the effectiveness of the Cuckoo Optimization Algorithm compared to the method used in the work of Chaker et al. (2019), and they also show that its performance is improved even compared to more advanced methods such as the Artificial Bee Colony algorithm, as in the work of Koubaa M et al. (2016). For these reasons, the COA method is tested to evaluate its effectiveness in the inspection and technical control field for the personnel primarily scheduling problem.

3.MATERIALS AND METHODS

The aims of this section are to presents the mathematical model proposed by Chaker et al. (2024), which provides a mathematical formulation for a real-world Multi-Skilled Staff Scheduling Problem in a Technical Control Company. The model was initially proposed and tested using CPLEX; however, real-world instances cannot be solved with this formulation due to its NP-hard nature and problem size.

To address real data, the authors employed a Greedy Randomized Adaptive Search Procedure (GRASP) metaheuristic to obtain acceptable solutions. The novelty of this research lies in providing a feasible alternative solution approach. Accordingly, their mathematical formulation is adopted here and implemented in MATLAB 2018 to resolve this principal Staff Scheduling Problem (SSP) using a population-based metaheuristic known as the Cuckoo Optimization Algorithm. Thus, the main contribution is the application of COA as an alternative method that overcomes the limitations encountered with the NP-hard formulation.

In this section, the first part of provides a detailed presentation of the mathematical formulation. The second part focuses on the metaheuristic used to optimize the problem, namely the COA.

3.1 Mathematical formulation

This subsection presents the multi-objective mathematical formulation proposed by Chaker et al. (2024) for the multi-skilled inspectors scheduling problem.

3.1.1 Objectives

The objectives defined by Chaker et al. (2024) are as follows:

- Minimize the variation in inspectors' premiums compared to the average total premiums.
- Minimize the variation in working hours compared to the average number of missions performed.
- Minimize the distances traveled by inspectors for control missions compared to the average distances traveled.
- Maximize client satisfaction with the assigned inspectors and the quality of service provided.
- Reduce the radiation dose received by all inspectors throughout X-ray inspection missions.

Furthermore, in the problem addressed, the defined objectives are contradictory, have different levels of importance, and use different units of measure. The Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) method is applied to define the weight of each objective. Table 1 summarizes the defined weights.

Table 1. Summary on objectives weights defined

N°	Objectives	Weight
01	Client preference	0,378
02	Financial equity	0,297
03	Working hours fairness	0,189
04	Distance traveled fairness	0,108
05	Radiographic dose distribution	0,027

3.1.2 Mathematical model

To develop a mathematical model for inspector scheduling in the technical control field, Chaker et al. (2024) define the next constraints:

- All control mission requires a certified inspector qualified for the specific method.
- The inspector assigned to each control mission is selected according to the nature of the mission.
- The experience need for a control mission must be greater than or equal to a minimum threshold defined by the human expert.
- A client may request a specific inspector to perform the required inspection tasks.
- The radiation dose limit allocated to each inspector must be respected.
- Compliance with labor code and applicable regulations must be ensured. The aim of this study is to solve the multi-skilled inspectors scheduling problem over a variable planning horizon while satisfying all stakeholder-defined constraints. The goal of the objective function is to minimize the weighted sum of all deviations from ideal targets across the five conflicting criteria:
- Respect of client recommendations and requests for specific inspectors.
- Fair distribution of working hours among inspectors.
- Equity in premiums earned by each inspector.
- Balanced number of destinations traveled for technical control missions.
- Equitable distribution of radiation doses absorbed by each inspector.

3.2 Cuckoo Optimization Algorithm

The Cuckoo Optimization Algorithm is a population-based metaheuristic designed to solve NP-hard optimization problems. It has demonstrated strong performance, particularly in scheduling applications, and is recognized as one of the most robust and recent algorithms in this category Yang and Deb (2009).

This method, proposed by Yang and Deb in 2009, based for the inspiration from the brood parasitism behavior of cuckoos. These birds always lay their eggs in the nests of other species and remove the host eggs to maximize their offspring's survival Koubaa et al. (2022), Payne et al. (2005). In COA, the eggs represent problem solutions, and a cuckoo egg symbolizes a newly generated solution Brown et al. (2007), Pavlyukevich (2007). If the host bird discovers the cuckoo egg, it is removed and replaced by a new solution Yang and Deb (2009). Even after hatching, the cuckoo chick ejects the host eggs from the nest. The cuckoo chick typically survives by consuming most of the food, leading to the starvation of host chicks Joshi et al. (2017).

In COA, problem variables are represented as an array called a "habitat," which corresponds to the cuckoo's living location Koubaa et al. (2022). This habitat is defined as $[x_1, x_2, x_3, ..., x_{nxar}]$, where $(x_1, x_2, ..., x_{nxar})$ are floating-point variable values. The objective function, termed the "profit function," is maximized and equals the habitat's profit. For minimization problems, the profit is defined as the negative of the habitat cost.

The optimization process begins by creating an initial population matrix of size $N_{pop} \times N_{var}$. Each cuckoo habitat is then assigned a random number of eggs between 5 and 20, reflecting natural cuckoo behaviour. All cuckoos lay their eggs within the Egg Laying Radius (ELR), calculated as follows:

$$\text{ERL} = \alpha \times (\,var\ Hi - var\ Low) \times \frac{Number\ of\ eggs\ current\ \ of\ cuckoo}{Sum\ of\ eggs}$$

where α is an integer representing the maximum ELR value.

After the cuckoos' chicks get bigger, they fly and found to an appropriate area where they can find eggs in nests similar to their own. Once the most suitable environment has been chosen, they will immigrate all the other cuckoos, and to reach this chosen target location, the migratory cuckoo travels a distance (λ %) then deviates (ϕ radians) from the goal arrival point. Koubaa et al. (2022), two parameters are considered for each Cuckoo such as:

$\lambda \sim U\,(0, 1)$ where the number is randomly chosen between 0 and 1.

$\Phi \sim U\,(-\omega, \omega)$ this parameter limits the target location (habitat) deviation (chosen as $\pi/6$ rad)

After one all the cuckoos have immigrated and chosen their target location, and we will now calculate an ELR for each Cuckoo, taking into account the number of eggs allocated to each bird. Then we will initiate a new laying process Joshi et al. (2017). The COA flowchart is presented as follows:

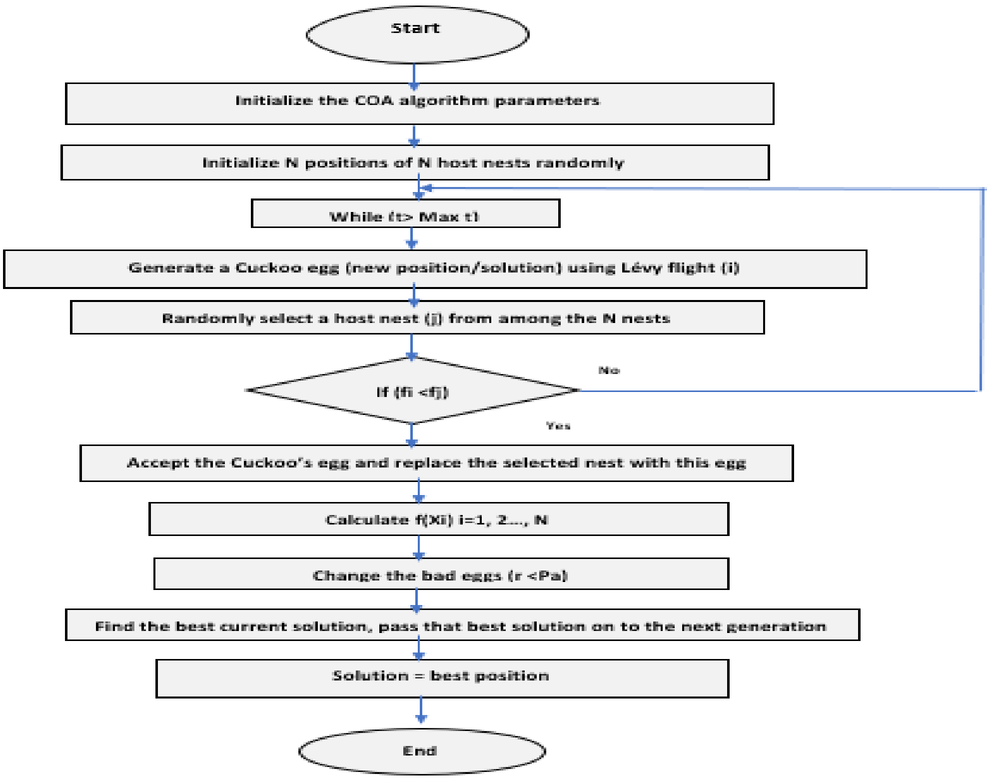

Figure 1 : The COA organization chart

4.Case study

To evaluate the most efficiency of this COA for the considered multi-skilled inspectors scheduling problem and to compare it with existing approaches, a series of computational experiments was carried out on the same benchmark test instances proposed by Chaker et al. (2019). These instances are based on real operational data collected from a technical control company and reflect realistic planning conditions in terms of number of inspectors, missions, destinations, and regulatory constraints.

The test set includes instances with different planning horizons and problem sizes, ranging from small cases solvable exactly by CPLEX to larger and more complex instances where exact methods become impractical. This configuration allows a fair comparison between exact and metaheuristic approaches in both low- and high-complexity scenarios. The input files used in this study (missions, inspectors' skills and certifications, client preferences, travel distances, premiums, and radiation dose parameters) are available online, as referenced in Chaker et al. (2024), ensuring full reproducibility of the experiments and enabling future comparisons with alternative algorithms.

4.1Programming environment

The proposed COA-based solution approach was implemented in MATLAB R2018a and executed on a standard laptop with the following specifications:

- Processor: Intel® Core™ i7-1075H CPU @ 2.60 GHz
- RAM: 8 GB
- Graphics card: NVIDIA GeForce GTX (4 GB)
- Hard disk: 500 GB

This computing environment is representative of commonly available hardware, which means that the reported computation times can realistically be achieved in typical industrial or academic settings. All methods compared in this study (CPLEX, GRASP, and COA) were run on the same machine to ensure a fair comparison of their computational performance.

4.2 RESULTS

To provide a comprehensive assessment of the proposed approach, the following table presents a comparative analysis of the results obtained for the Multi-Skills Inspectors Scheduling Problem using three different methods: CPLEX, GRASP, and COA. For each test instance, the table reports the coverage rate, the resolution time and the objective function value, which allows the evaluation of both computational efficiency and also the solution quality.

The comparison highlights the ability of COA to maintain a 100% coverage rate while producing competitive or improved objective values, particularly on medium- and large-size instances where exact optimization with CPLEX reaches its time limit. In addition, the results illustrate the robustness of COA relative to GRASP, both in terms of stability and convergence behaviour of the solutions obtained across the different test cases.

To further assess the effectiveness of COA in solving the NP-hard Technical Inspectors Scheduling Problem, a series of experiments was conducted using the same benchmark instances proposed by Chaker et al. (2024). In this case study, the COA based scheduling approach yields better and best results than the GRASP method: COA converges to optimal solutions (as validated by CPLEX) for small instances and demonstrates superior performance for larger instances.

Two additional contributions emerge from the comparison between the assignments generated by COA and GRASP. First, COA outperforms GRASP by providing more satisfactory results in terms of maximum coverage. Second, the total number of assigned positions is higher with COA, while the fitness (objective) values obtained are lower than those produced by GRASP, confirming the effectiveness of COA for this class of scheduling problems.

Table 2: A comparative analysis of the results obtained for the Multi-Skills Inspectors Scheduling Problem using three different methods

Test N°	Number of				CPLEX				GRASP			COA		
	Day	Inspector	Destination	Mission	The coverage rate in %	The objective function	Optimality	The time resolution in (s)	The coverage rate in %	The objective function	The time resolution in (s)	The coverage rate in %	The objective function	The time resolution in (s)
1	5	4	1	5	100%	26,09	Confirmed	32,714	100%	26,09	0,202	100%	26,09	0,157
2	5	5	1	7	100%	26,48	Confirmed	33,218	100%	26,48	0,705	100%	26,48	0,633
3	5	5	1	7	100%	25,31	Confirmed	42,861	100%	25,31	1,002	100%	25,31	0,745
4	6	6	1	9	100%	27,22	Confirmed	65,083	100%	27,22	2,822	100%	27,22	2,075
5	6	5	1	8	100%	23,15	Confirmed	27,228	100%	23,15	0,302	100%	23,15	0,098
6	6	6	3	9	100%	37,22	Confirmed	111,309	100%	37,22	2,822	100%	37,22	1,978
7	6	13	3	21	100%	59,60	Confirmed	202,981	100%	59,60	4,016	100%	59,60	2,876
8	14	12	3	22	100%	59,78	Confirmed	282,314	100%	59,78	4,228	100%	59,78	3,017
9	14	15	2	37	100%	64,22	No	Time Limit	100%	64,22	6,471	100%	62.11	63.140
10	6	35	3	79	100%	143,67	No	Time Limit	100%	143,67	18,061	100%	143.67	16.460
11	7	55	2	88	-	-	No	-	100%	161,77	32,664	100%	161.77	30.675
12	7	62	3	102	-	-	No	-	100%	189,01	77,349	100%	187.67	73.423
13	21	100	3	122	-	-	No	-	98%	200,76	102,664	100%	215.38	114.759
14	21	124	2	182	-	-	No	-	82%	257,59	192,781	100%	278.28	260.483
15	21	150	3	222	-	-	No	-	77%	318,22	211,030	91.44%	407.35	317.974

CONCLUSION AND PERSPECTIVES

This work addressed a multi-skilled inspectors scheduling problem arising in the technical inspection sector. Given the NP-hard nature of this problem, exact methods quickly become impractical for real-world applications, which motivates the use of advanced metaheuristic approaches. In this context, the Cuckoo Optimization Algorithm was proposed as an effective solution method and was evaluated on a real case study from a Tunisian technical inspection company.

The numerical experiments show that COA is capable of generating high-quality schedules within reasonable computation times. When compared with the GRASP algorithm, COA consistently delivers better solutions and overall performance, achieving higher coverage and more efficient utilization of multi-skilled inspectors. These results confirm both the robustness and the practical relevance of COA for solving complex personnel scheduling problems.

From an academic perspective, this study contributes to the literature on metaheuristic approaches for workforce planning by highlighting the potential of the Cuckoo Optimization Algorithm in the context of technical inspection activities. From a managerial perspective, the proposed approach provides a useful decision-support tool that can help technical inspection companies improve planning efficiency, service quality, and operational performance.

Future research directions include extending the model to incorporate additional real-world constraints, such as inspectors' preferences, regulatory changes, and uncertainty in inspection demand. Another promising avenue is the investigation of hybrid or hyper-heuristic strategies that combine COA with other metaheuristics to further enhance solution quality and computational robustness.

REFERENCES

Al-Rawi O, and Mukherjee T, 2019. Application of linear programming in optimizing labour scheduling. J Math Finance, 09(03): 272–285. https://doi.org/10.4236/jmf.2019.93016

Bowden Z, and Ragsdale C, 2018. The truck driver scheduling problem with fatigue monitoring. Decis Support Syst, 110: 20–31. https://doi.org/10.1016/j.dss.2018.03.002

Brown C, Liebovitch L, and Glendon R, 2007. Lévy flights in Dobe Ju/hoansi foraging patterns. Human Ecol, 35:129–138.

Bürgy R, Michon-Lacaze H, and Desaulniers G, 2019. Employee scheduling with short demand perturbations and extensible shifts. Omega (United Kingdom), 89: 177–192. https://doi.org/10.1016/j. omega.2018.10.009

Chaker B, Mohamed HA, and Diala D, 2019. A Framework for Multi-Skills Inspectors Scheduling with Client Preferences in Service Industry: Real Case. In International Colloquium on Logistics and Supply Chain Management, LOGISTIQUA 2019.

Chaker B, Mohamed H A, and Diala D, 2024. Multi-objective personnel scheduling problem with multiple qualifcation and client's satisfaction: real case. Flexible Services and Manufacturing Journal. DOI:10.1007/s10696-024-09570-w

Chen R, Liang C, Gu D, and Zhao H, 2020. A competence-time-quality scheduling model of multi-skilled staf for IT project portfolio. Comput Ind Eng,139:106-183. https://doi.org/10.1016/j.cie.2019. 106183

Ciancio C, Laganà D, Musmanno R, and Santoro F, 2018. An integrated algorithm for shift scheduling problems for local public transport companies. Omega (United Kingdom), 75:1339–1351. https://doi. org/10.1016/j.omega.2017.02.007

Denkena B, Dittrich M, and Winter F, 2017. Competence-based personnel scheduling through production data. Proced CIRP, 63:265–270. https://doi.org/10.1016/j.procir.2017.03.114

Hassani R, Desaulniers G, and Elhallaoui I, 2020. Real-time personnel re-scheduling after a minor disruption in the retail industry. Comput Oper Res, p120. https://doi.org/10.1016/j.cor.2020.104952

Henao C, Muñoz J, and Ferrer J, 2019. Multiskilled workforce management by utilizing closed chains under uncertain demand: a retail industry case. Comput Ind Eng, 127:74–88. https://doi.org/10. 1016/j.cie.2018.11.061

Hochdörfer J, Hedler M, and Lanza G, 2018. Staf scheduling in job rotation environments considering ergonomic aspects and preservation of qualifcations. J Manuf Syst, 46:103–114. https://doi.org/10. 1016/j.jmsy.2017.11.005

Janacek J, Kohani M, Koniorczyk M, and Marton P, 2017. Optimization of periodic crew schedules with application of column generation method. Transp Res Part C Emerg Technol, 83 : 165–178. https:// doi.org/10.1016/j.trc.2017.07.008

Joshi A S, Kulkarni O, Kakandikar G M, and Nandedkar V M, 2017. Cuckoo Search Optimization- A Review. Materials Today: Proceedings, 4(8):7262–7269. doi:10.1016/j. matpr.2017.07.055

Koubaa M, Mohamed HA and Beji N, 2022. Solving A Real Case Of Seafaring Staff Scheduling Problem Using Cuckoo Optimization Algorithm. International Journal Of Applied Metaheuristic Computing (IJAMC), (13(1)), p 19. DOI:10.4018/IJAMC.298316

Koubaa M, Elloumi S, and Dhouib S, 2016. Optimising case study personnel scheduling problem using an artifcial bee colony algorithm. Int J Shipp Transp Logist , 8(5): 552–567.
https://doi.org/10.1504/ IJSTL.2016.10000187

Mac-Vicar M, Ferrer J, Muñoz J, and Henao C, 2017. Real-time recovering strategies on personnel scheduling in the retail industry. Comput Ind Eng, 113:589–601. https://doi.org/10. 1016/j.cie.2017.09.045

Pavlyukevich I, 2007. Lévy flights, non-local search and simulated annealing. J Comput Phys, 226:1830–1844.

Payne R, Sorenson M, and Klitz K, 2005. The Cuckoos. Oxford University Press, New York.

Rama S, Srividya S, and Bellatti D, 2017. A linear programming approach for optimal scheduling of workers in a transport corporation. Int J Eng Trends Technolo, 45(10):482–487. https://doi.org/10.14445/ 22315381/IJETT-V45P291

Shiau JY, Huang MK, and Huang CY, 2020. A hybrid personnel scheduling model for staf rostering problems. Mathematics, 8(10):1–20. https://doi.org/10.3390/math8101702

Wongwien T, and Nanthavanij S, 2017. Priority-based ergonomic workforce scheduling for industrial workers performing hazardous jobs. J Ind Prod Eng, 34(1): 52–60. https://doi.org/10.1080/21681015. 2016.1192567

Yang X S, and Deb S, 2009. Cuckoo search via Lévy flights. In: Proceedings of World Congress on Nature & Biologically Inspired Computing. IEEE Publications, USA,pp: 210–214