The Bi-level Assembly Flow-Shop Scheduling Problem with Batching and Delivery with Capacity Constraint

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Abstract. In most manufacturing and assembly systems, a number of operations are performed on each job. Most of these operations are performed in the same order on all tasks, ie the works flow in the same direction. In such an environment, known as flow shop, the machines are arranged in series. In this the bi-Level assembly flow-shop scheduling problem with Capacity Constrains batching and delivery system is presented. Here, m is a single machine that do different parts of the job, and in the second part, number of machines have the duty of assembly. In this paper, a mixed nonlinear integer math model is formulated. The objective of this model is include minimizing the cost of delays, delivery, and categorization. For solving the model in small dimensions, the Branch and Bound method are used in GAMS and finally numerical examples and Analysis are done.

Keywords: Assembly flow shop · Scheduling · Batched delivery system · Mathematical model

1 Introduction

The first study of two-stage production scheduling was reviewed [1]. With the advent of modern technologies in production and industry, many efforts have been made to coordinate production and distribution in supply chain management [2, 3]. The production planning process, which helps to find the optimal use of available resources to meet market demand, has always been one of the most important activities in manufacturing and service companies. Meanwhile, the issue of scheduling and sequencing operations as one of the final stages of production planning, plays a significant role in achieving its goals. In the manufacturing industry, the issue of scheduling, depending on the production environment and the constraints and functions of the target, can be a simple or very complex issue. The issue of flow shop has attracted the attention of many researchers due

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to its widespread use in industry and economics. Flow Shop is one of the optimization issues in computer science and operations research, which is also called line layout. This refers to a process or shop that runs on a flow when all jobs have the same processing path. It is used for frequent productions that include constant job flows and a relatively large production volume. Flow control in these jobs is easy in this case, but it is difficult to respond to product diversity. The main goal is to find the best plan and arrangement for those jobs in order to minimize longevity.

Nowadays, various industries are moving towards lowering their price. In this regard, in manufacturing companies, production planning and distribution is an important issue. However, in supply chain planning, including classification and delivery, the cost of classification and the capacity of the categories in question have not been considered.

The structure of the article is as follows: in Sect. 2 the research background is presented and then in Sect. 3 the problem is stated and the problem is formulated by presenting a programming model of mixed nonlinear integer and finally, in Sect. 4, a case study and performance evaluation are reviewed.

2 Literature Review

A scheduling process is a process in which resources are allocated to perform a set of tasks over a period of time, and generally two sets of objective functions can be used in scheduling problem. Rahman et al. [4] design a mathematical model and study the production and distribution issues with start-up time, which depends on the order for several customers. To solve these problems, three meta-heuristic algorithms were used. The goal is to minimize the total cost of the flow shop. A case study in industry has been used to validate the problem.

Jabbari et al. [5] developed a mathematical model for examining the timing of a custom production system that includes a shop flow production line with a parallel assembly line that produces different products in two stages. The goal is to increase the manufacturing time of goods using efficient planning. Because the NP-hard model uses genetic algorithm (GA) and particle swarm optimization methods to solve the model. Zhang et al. [6] examined preventive maintenance activities in a two-step flow shop schedule using a MILP model. Heuristic method was used to solve the model [7–12]. Yang et al. [12] investigated a new distributed assembly flow scheduling issue with flexible assembly and batch delivery. The goal is to minimize the total cost of delivery and delays. Seven algorithms including variable neighborhood descent (VND) algorithm, and two Iterated Greedy (IG) have been used to solve the model. The results showed that the proposed batch allocation could significantly improve the solution.

Basir et al. [13] studied integrated production and distribution planning on two stages of flow shop assembly with batch delivery system. Their mathematical model is MILP. The goal is to plan jobs in two-phase flow shop and deliver completed products in an appropriate number with a minimum number of weighted latency jobs and total grouped delivery costs. An improved two-level genetic algorithm has been used to solve the model. Ceylan et al. [14] investigated a coordinated planning problem for a multi-stage supply chain network. The MILP problem has two purposes. The goal is to minimize the total cost of the supply chain. The structure of this supply chain is multi-product and multi-period. To integrate the issue of flexible flow shop planning, a supply chain network has been integrated. The results showed that the sum of weights is the best MODM method to solve the problem.

Cheng and Kahlbacher [15] raised issues related to batch delivery planning [16, 17]. Today, the main industries are moving towards Just in Time (JIT) production and expanding the world market, manufacturing companies are moving more and more towards competition in order to reduce their costs. Therefore, integrated production and distribution planning is very important for manufacturing companies [18]. The problem of two-stage assembly is widely used in industry.

Mazdeh and Rostami [19] proposed a mixed linear algorithm and a single branch algorithm for dual-flow scheduling problems to minimize latency and delivery costs. The problem of flow shop production scheduling is an issue of np-hard optimization in the production scheduling literature [20]. Belabid et al. [21] designed a mathematical model for the flow shop problem that has a start-up time independent of the sequence. The mathematical model is of the MILP type. The goal is to minimize the maximum completion time. Several innovative and meta-innovative methods have been used to solve the model. Taxido et al. [22] examined the issue of permutation flow shop scheduling problem using a combination of firefly algorithm and variable neighborhood search algorithm. The flow shop scheduling issue is an NP-hard issue. In order to find high quality solutions in a reasonable computational time, heuristic and meta-heuristic algorithms have been used to solve the problem. In order to test the effectiveness and efficiency of the proposed method, we used a set of benchmark samples with different sizes of articles.

Wang et al. [23] proposed a mathematical model to address the issue of flow shop schedule delivery for multiple customers. In this case, first the products are produced as alternatives and then they are delivered to multi customers. The purpose of this article is to minimize the total cost of delay and batch delivery. To solve the model, innovative methods of genetic algorithm and variable neighborhood search and a new meta-heuristic method have been used. Al-Bihadili et al. [24] examined a multi-objective flow shop optimization model with the arrival of new work and machine failure. The purpose of this is to increase the working time according to the stability and strength. To solve the model, the Biased Randomized algorithm was used to repeat the greed [25].

Ochi et al. [26] studied the flow shop assembly schedule, which aims to minimize make span. To solve the model, iterated greedy-based method was used and to improve the quality of the solution, four search methods were used. Then, comparative results between the performances of algorithms were performed. Pessoa et al. [27] investigated a flow shop planning issue with delivery dates and cumulative returns. Their goal is to maximize profits. Computational experiments were performed by considering the methods of solving the problem and the local search method.

In this paper, the issue of flow shop assembly schedule has been studied, and the delivery and classification system has also been considered in this issue. This is a NP-hard model. The purpose of the model is to minimize the cost of delays, delivery and classification. To solve the MILP model, the branch and boundary method has been used.

3 Problem Description

In this paper we have N jobs belonging to H customer and n_j denote the total number of jobs related to the customer by j, so the sum of the total number of jobs related to customers shows the total jobs N.

In order to complete each task, each M part must be completed, these components are completely unique, and in the first stage of the process, there is an independent M machine that is responsible for performing the various components of each task.

When the components of each work are completed by the machines in the first stage, in order to assemble the parts, the work must be assigned to one of the assembly machines that is free. After completing the work, it is necessary to decide on the classification and submission of work. After completion, each task can be sent to the customer, or if the classification is done, it must wait for the completion of all tasks related to that category, and after completing all the tasks in that category, then it will be sent to the customer. Due to this, the maximum number of categories can be considered equal to the total number of works, and according to the explanations given, if the category is sent to the customer, the time of sending the category is equal to the time when the last task related to that category is completed. The cost that we accept for the delivery of each category is proportional to the size of the category, but the size of the categories is not unlimited, so that if the total size of the work related to a customer exceeds the size of the category We have to increase the number of categories, which will cost us more categories.

The goal is to minimize the total delay time, delivery costs and number of batches. However, due to the target sentences that are not similar in terms of gender, we use the scores of G and δ for delays as well as categorization, respectively. Therefore, the objective function is represented as Eq. (1). In the real world example, when there is a delay in delivery to the customer, there is a penalty unit for the delay, as well as a fee for the categories to be done by the relevant personnel, which is considered here ℓ. Waiting to complete other customer orders and placing orders in one batch can increase the delay of a number of orders and on the other hand reduce delivery costs. In fact, this study seeks balance between delay and delivery cost in the supply chain.

Bank et al. showed that the two-machine flow shop problem with the objective function of the sum of delays without considering the reduction is Np-hard.

Since the problem under study, in addition to being two-stage, also includes classification and capacity issues, and the objective function is the sum of delays, delivery costs and classification costs, so the complexity of this issue is more than the issue studied by Bank et al. and is considered NP-hard. It is worth noting that the machine that is available during the operation is not allowed to perform other operations at that time.

3.1 Model Assumptions

1. All machines are available in zero time.
2. Each work consists of components that must first be performed on the machine in the first stage and then transferred to the assembly machines for assembly in the second stage.
3. Preparation time is considered zero and all works can start at zero time.
4. Stoppage due to line failure or maintenance operations is not considered in the issue.

5. Each part of the work, when placed on a machine, is on that machine until the end of the operation, and it is not allowed to interrupt work either in the first stage or in the second stage.
6. The assembly machines in the second stage are of the same material and the part can be placed on the available assembly machine after the completion of all the components.
7. Categories that include tasks always include at least one task.

Indices

i	Job Index $i = 1, 2, 3, ..., n_j$
j	Customer Index $j = 1, 2, 3, ..., H$
m	Index of machines in the first stage $m = 1, 2, 3, ..., M$
q	Index of assembly machines in the second stage $q = 1, 2, 3, ..., Q$
k	Job position index in the first stage $k = 1, 2, 3, ..., N$
b	Classification index $b = 1, 2, 3, ..., N$

Parameters

P_{ijm}	Process time i for client j on machine m
S_{ij}	Assembly time work i for customer j
D_{ij}	Delivery time i for customer j
D_j	Delivery time for the customer j
g_i	Work size i
G	Handle size
l	The cost of categorizing each category
δ	Cost per delay unit

Decision variables

P'_{km}	Work process time on position k on machine m (in the first step)
X_{ijk}	This variable is 1 when job i is related to client j in position k, otherwise it is zero
F_{km}	Completion time of a work component that is on the k position on the m machine
FF_k	Completion time of all components of the work or when the work is ready for assembly
S'_k	Assembly time of the work that is on the k position
C_{kq}	Completion time k on assembly machine q (If not assigned to machine q, this time is zero.)
CT_{kq}	Completion time of the last work before k th which is assigned to the assembly machine q
R_{kq}	The time it takes for assembly work k to start on machine q
C_{ij}	Completion time of task i, which belongs to customer j
Y_{kq}	This variable will be equal to 1 when work k is assigned to the assembly machine q, otherwise it will be zero
C_{bj}	Completion time of category b belongs to customer j

RR_{ij} Time to send work i to client j
Z_{ijb} If the i-th job belongs to the j-th customer in category b, it is 1, otherwise it is zero
V_{jb} If the job belonging to customer j is in category b it is 1, otherwise it is zero ($\forall_j \sum_b V_{jb}$ equal to the number of categories owned by customer j)
SSV_{bj} Category b size belongs to the customer j
V'_{jb} Number of components of category b belonging to the customer j

3.2 Mixed Integer Nonlinear Programming Model

$$Min \sum_{j=1}^{H}\sum_{i=1}^{n_j} \delta \cdot T_{ij} + \sum_{j=1}^{H}\sum_{b=1}^{N} V_{jb} \cdot D_j + \sum_{b=1}^{N} l \cdot V'_b \tag{1}$$

$$T_{ij} \geq 0 \qquad \forall i, \forall j \tag{2}$$

$$T_{ij} \geq RR_{ij} - d_{ij} \qquad \forall i, \forall j \tag{3}$$

$$RR_{ij} + M(1 - z_{ijb}) \geq C_{bj} \qquad \forall i, \forall j, \forall b \tag{4}$$

$$C_{bj} + M(1 - z_{ijb}) \geq C_{ij} \qquad \forall j, \forall b, \forall i \tag{5}$$

$$C_{ij} + M(1 - x_{ijk}) \geq \sum_{q} C_{kq} \tag{6}$$

$$C_{1q} = Y_{1q} \times (FF_1 + S'_{kq}) \qquad \forall q \tag{7}$$

$$C_{kq} = Y_{kq} \times (R_{kq} + S'_{kq}) \qquad \forall k, k \neq 1, \forall q \tag{8}$$

$$R_{kq} \geq FF_k \qquad \forall k, k \neq 1, \forall q \tag{9}$$

$$R_{kq} \geq CT_{kq} \qquad \forall k, k \neq 1, \forall q \tag{10}$$

$$CT_{kq} \geq C_{(e-1)q} \qquad \forall k, k \neq 1, \forall q, e = 2, ..., k \tag{11}$$

$$F_{km} = \sum_{a=1}^{k} P'_{km} \qquad \forall k, \forall m \tag{12}$$

$$FF_k \geq F_{km} \qquad \forall k, \forall m \tag{13}$$

$$\sum_{k=1}^{N} X_{ijk} = 1 \qquad \forall i, \forall j \tag{14}$$

$$\sum_{j=1}^{H} \sum_{i=1}^{n_j} X_{ijk} = 1 \qquad \forall K \tag{15}$$

$$\sum_{q} Y_{kq} = 1 \qquad \forall K \tag{16}$$

$$P'_{km} = \sum_{j=1}^{H} \sum_{i=1}^{n_j} (X_{ijk} \cdot P_{ijm}) \qquad \forall k, \forall m \tag{17}$$

$$S'_k = \sum_{j=1}^{H} \sum_{i=1}^{nj} (X_{ijk} \cdot S_{ij}) \qquad \forall k \tag{18}$$

$$\sum_{j=1}^{H} Z_{ijb} \leq 1 \qquad \forall i, \forall b \tag{19}$$

$$\sum_{b=1}^{N} Z_{ijb} = 1 \qquad \forall i, \forall j \sqrt{b^2 - 4ac} \tag{20}$$

$$-\sum_{i=1}^{n_j} Z_{ijb} + M \cdot (V_{jb}) \geq 0 \qquad \forall j, \forall b \tag{21}$$

$$\sum_{i=1}^{n_j} Z_{ijb} + M \cdot (1 - V_{jb}) > 0 \qquad \forall j, \forall b \tag{22}$$

$$SV_b = \sum_{i=1}^{N} \sum_{j=1}^{H} Z_{ijb} \cdot g_i \qquad \forall b \tag{23}$$

$$V'_b = \left\lceil \frac{SV_b}{G} \right\rceil \qquad \forall b \tag{24}$$

Objective function (1) shows the minimization of total delays as well as delivery costs and classification costs. Constraints (2) and (3) calculate the delay for each task. Constraint (4) Calculates the delivery time for each task, which is equal to the time it takes to complete the category. Constraint (5) Calculates the completion time of each category corresponding to the longest completion time in this category. Constraint (6) Calculates the time of completion of work i related to the customer j and related to the assembly machine assigned to it. Constraints (7) and (8) calculate the time to complete the task, which is in the first and kth position. Constraints (9), (10) and (11) are necessary restrictions for use. Constraint (13) according to the definition of the variable in the description of variables. Constraint (12) Calculates the completion time of a task related to its own process time. Constraints (14) and (15) each job is only for one sequence, and each sequence is occupied by only one job, respectively. Constraint (16) they guarantee that each job will be assigned to only one assembly machine. Constraint (17) calculates the process time of work in position k on machine m. Constraint (18) calculates the assembly time of the work in position k. In other words, constraints (17) and (18) convert the process and assembly time for work i to working time in position k. Constraint (19) prevents the tasks of different clients from being grouped together. Constraint (20) guarantee that each job falls into only one category. Constraints (21) and (22) ensure that each category is created when at least one job is assigned to it, otherwise V_{jb} will be zero. Constraint (23) specifies the total size of each category. The Constraint (24) specifies the number of batches after the batches are divided into parts so that if the batches have a size higher than the batch capacity, they can be divided into more batches. Constraints (7) and (8) are nonlinear, because the variable of decision Y_{kq} is multiplied by the variables FF_k and R_{kq}.

4 Solution Method

The assembly machine is placed for delivery to the customers for stacking the parts on top of each other, which is done with the aim of achieving three criteria, minimizing delays, delivery cost and classification cost, so the above purpose is different from Non-homogeneous Delays We use the penalty rate to match the three criteria under consideration. In this section, a mixed nonlinear integer model is formulated, in which Bank et al. (2012) showed that the two-step flow shop problem with the aim of minimizing delays is the NP-Hard problem [6, 28]. Therefore, the model of the problem we are investigating, which is much more complex, is of the NP-Hard type. And the innovation of this article is that it creates capacity for categories that are sent to customers.

5 Case Study and Performance Evaluation

In this section, an example of a factory is mentioned that for the delivery of 7 types of work, each work consists of 10 sequences on 3 machines, and in the next stage, the parts are mounted on 2 assembly machines, and finally the classification is done on them. Shipped to 4 potential customers. (Capacity of each category is 20). The above problem has been solved with GAMS 24.8.2 software and with a computer with specifications, CORE i5 processor, RAM 4 and 1 GB graphics card and the BARON solver has been used. As illustrated in Table 1, if the capacity for work is considered and the categories have a certain capacity, the number of category will increase. And the model is formulated so that both results are visible once implemented by the software.

Table 1. Computational results

Objective function	Number of batches	Number of batches considering capacity	Total delay time
1018	4	16	133

Because the factory can use different batches but with the same capacity, the scenario by performing the problem in 150 times with different parameters to the capacity of the batch, while comparing the condition that the batches have capacity and unlimited capacity mode, the result was that Unlimited capacity for this problem is the capacity of the handle above 62 units, which is also evident in Fig. 1.

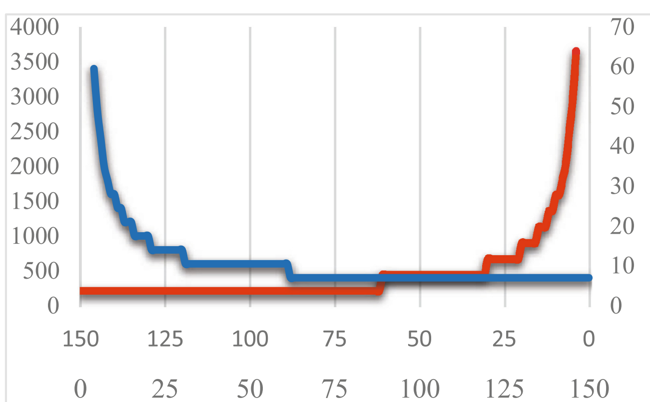

Fig. 1. Two-scale diagram of comparisons of the number of categories and the objective function to the capacity of the category

In fact, according to the problem data, the minimum number of categories and the objective function are 4 and 418 units, respectively, and the diagram from the capacity of 62 units upwards continues completely horizontally. According to the bubble diagram of Fig. 2, where the radius of the bubble indicates the number of categories, it is important to note that as the capacity of the category decreases, the number of categories as well as the objective function increases exponentially.

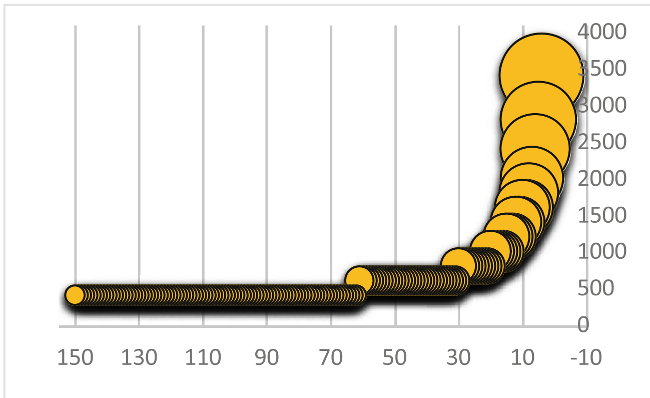

Fig. 2. Bubble diagram comparing the number of categories, the objective function and the capacity of the category

6 Conclusions

In this paper, the problem of two-stage assembly workflow using batch delivery system in order to minimize the overall cost of delay and delivery cost is investigated. A new mathematical model of nonlinear integer programming is presented. Due to the fact that the software is not able to provide the model answer for large dimensions in a reasonable time, so to solve the small size of the model. Due to the approach to the reality of the mentioned issue, there was no restriction for the categories, which is not the case in reality. This is further achieved by giving volume to tasks and capacity to categories And the analysis on the results includes the points that by reducing the capacity of the category, increasing the number of categories and consequently increasing the objective function, which according to the type of factory and type of products, this model can be worked on a special case. In this regard, to get closer to reality, a routing model can be added for potential customers, and the costs of quality control or warehouse and inventory control can be very important for future studies.

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References

1. Lee, C.-Y., Cheng, T., Lin, B.M.T.: Minimizing the makespan in the 3-machine assembly-type flowshop scheduling problem. Manage. Sci. **39**(5), 616–625 (1993)

2. Goodarzian, F., Wamba, S.F., Mathiyazhagan, K., Taghipour, A.: A new bi-objective green medicine supply chain network design under fuzzy environment: hybrid metaheuristic algorithms. Comput. Indust. Eng. **160**, 107535 (2021)
3. Baker, K.R.: Introduction to Sequencing and Scheduling. John Wiley & Sons, Hoboken (1974)
4. Rahman, H.F., Janardhanan, M.N., Chuen, L.P., Ponnambalam, S.G.: Flowshop scheduling with sequence dependent setup times and batch delivery in supply chain. Comput. Indust. Eng. **158**, 107378 (2021)
5. Jabbari, M., Tavana, M., Fattahi, P., Daneshamooz, F.: A parameter tuned hybrid algorithm for solving flow shop scheduling problems with parallel assembly stages. Sustain. Oper. Comput. **3**, 22–32 (2021)
6. Zhang, Z., Tang, Q.: Integrating flexible preventive maintenance activities into two-stage assembly flow shop scheduling with multiple assembly machines. Comput. Indust. Eng. **159**, 107493 (2021)
7. Goodarzian, F., Kumar, V., Abraham, A.: Hybrid meta-heuristic algorithms for a supply chain network considering different carbon emission regulations using big data characteristics. Soft. Comput. **25**(11), 7527–7557 (2021). https://doi.org/10.1007/s00500-021-05711-7
8. Goodarzian, F., Kumar, V., Ghasemi, P.: A set of efficient heuristics and meta-heuristics to solve a multi-objective pharmaceutical supply chain network. Comput. Indust. Eng. **158**, 107389 (2021)
9. Goodarzian, F., Taleizadeh, A.A., Ghasemi, P., Abraham, A.: An integrated sustainable medical supply chain network during COVID-19. Eng. Appl. Artif. Intell. **100**, 104188 (2021)
10. Ghasemi, P., Goodarzian, F., Gunasekaran, A., Abraham, A.: A bi-level mathematical model for logistic management considering the evolutionary game with environmental feedbacks. Int. J. Logist. Manage. (2021). (ahead-of-print). https://doi.org/10.1108/IJLM-04-2021-0199
11. Goodarzian, F., Bahrami, F., Shishebori, D.: A new location-allocation-problem for mobile telecommunication rigs model under crises and natural disasters: a real case study. J. Ambient. Intell. Humaniz. Comput. 1−19 (2021). https://doi.org/10.1007/s12652-021-03461-w
12. Yang, S., Xu, Z.: The distributed assembly permutation flowshop scheduling problem with flexible assembly and batch delivery. Int. J. Prod. Res. **59**(13), 4053–4071 (2021)
13. Basir, S.A., Mazdeh, M.M., Namakshenas, M.: Bi-level genetic algorithms for a two-stage assembly flow-shop scheduling problem with batch delivery system. Comput. Ind. Eng. **126**, 217–231 (2018)
14. Ceylan, Z., Tozan, H., Bulkan, S.: A coordinated scheduling problem for the supply chain in a flexible job shop machine environment. Oper. Res. Int. Journal **21**(2), 875–900 (2021). https://doi.org/10.1007/s12351-020-00615-0
15. Cheng, T., Kahlbacher, H.: Scheduling with delivery and earliness penalties. Asia-Pacific J. Oper. Res. **10**(2), 145–152 (1993)
16. Goodarzian, F., Abraham, A., Fathollahi-Fard, A.M.: A biobjective home health care logistics considering the working time and route balancing: a self-adaptive social engineering optimizer. J. Comput. Des. Eng. **8**(1), 452–474 (2021)
17. Kazemi, H., Mazdeh, M.M., Rostami, M.: The two stage assembly flow-shop scheduling problem with batching and delivery. Eng. Appl. Artif. Intell. **63**, 98–107 (2017)
18. Potts, C.N., Sevast'Janov, S.V., Strusevich, V.A., Van Wassenhove, L.N., Zwaneveld, C.M.: The two-stage assembly scheduling problem: complexity and approximation. Oper. Res. **43**(2), 346–355 (1995)
19. Mazdeh, M.M., Rostami, M.: A branch-and-bound algorithm for two-machine flow-shop scheduling problems with batch delivery costs. Int. J. Syst. Sci. Oper. Logist. **1**(2), 94–104 (2014)
20. Garey, M.R., Johnson, D.S., Sethi, R.: The complexity of flowshop and jobshop scheduling. Math. Oper. Res. **1**(2), 117–129 (1976)

21. Belabid, J., Aqil, S., Allali, K.: Solving permutation flow shop scheduling problem with sequence-independent setup time. J. Appl. Math. **2020**, 1–11 (2020). https://doi.org/10.1155/2020/7132469
22. Taxidou, A., Karafyllidis, I., Marinaki, M., Marinakis, Y., Migdalas, A.: A hybrid firefly - VNS algorithm for the permutation flowshop scheduling problem. In: Sifaleras, A., Salhi, S., Brimberg, J. (eds.) Variable Neighborhood Search: 6th International Conference, ICVNS 2018, Sithonia, Greece, October 4–7, 2018, Revised Selected Papers, pp. 274–286. Springer International Publishing, Cham (2019). https://doi.org/10.1007/978-3-030-15843-9_21
23. Wang, K., Luo, H., Liu, F., Yue, X.: Permutation flow shop scheduling with batch delivery to multiple customers in supply chains. IEEE Trans. Syst. Man Cybern. Syst. **48**(10), 1826–1837 (2017)
24. Al-Behadili, M., Ouelhadj, D., Jones, D.: Multi-objective biased randomised iterated greedy for robust permutation flow shop scheduling problem under disturbances. J. Oper. Res. Soc. **71**(11), 1847–1859 (2020)
25. Goodarzian, F., Hosseini-Nasab, H., Muñuzuri, J., Fakhrzad, M.B.: A multi-objective pharmaceutical supply chain network based on a robust fuzzy model: a comparison of meta-heuristics. Appl. Soft Comput. **92**, 106331 (2020)
26. Ochi, H., Driss, O.B.: Scheduling the distributed assembly flowshop problem to minimize the makespan. Procedia Comput. Sci. **164**, 471–477 (2019)
27. Pessoa, L.S., Andrade, C.E.: Heuristics for a flowshop scheduling problem with stepwise job objective function. Eur. J. Oper. Res. **266**(3), 950–962 (2018)
28. Goodarzian, F., Ghasemi, P., Gunasekaren, A., Taleizadeh, A.A., Abraham, A.: A sustainable-resilience healthcare network for handling COVID-19 pandemic Ann. Oper. Res. 1−65 (2021). https://doi.org/10.1007/s10479-021-04238-2