Websites:
http://www.sciencepub.net/nature
http://www.sciencepub.net

Emails:
naturesciencej@gmail.com
editor@sciencepub.net

Nature and Science

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Providing an algorithm developed for two-sided assembly line balancing problem

Dr. Alireza Irajpour, Amin Akafpour

Islamic Azad University, Qazvin Branch, Department of Management, Qazvin, Iran
Email Address: a.akafpour@qiau.ac.ir

Abstract: According to the performed studies, one of the barriers of productivity in which many companies are involved is assembly line balance problem of which solution requires application of scientific techniques. In Iran, one of the major reasons for failure to use the industrial units capacities is lack of balance between production and assembly lines. Since one of the considerable problems for the production employees is production lines balance, main purpose of this research is to introduce scientific techniques and application of suitable methods for balancing assembly lines which will be performed by introducing and presenting a developed heuristic algorithm for two -sided assembly lines balance with regard to tasks symmetry constraint. The above developed algorithm will consider two major goals ; first goal : presentation of a heuristic technique for balancing two-sided assembly lines and comparing its efficiency with optimal answers obtained from accurate methods, second goal: relative comparison of efficiency of three techniques of the most efficient Max T،Max F،Max PW priority laws

[Dr. Alireza Irajpour, Amin Akafpour. **Providing an algorithm developed for two-sided assembly line balancing problem**. Nat Sci 2022; 20(4);20-29]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 3. doi:10.7537/marsnsj200422.03.

Key words: balancing two-sided assembly lines, tasks symmetry constraint, heuristic techniques

1. Introduction:

Today, we are in the world which is regarded as postmodern business world. For this reason, we should make some changes in procedures especially in production environments with use of modern needs and new technologies and use of scientific techniques so that we can play role in fulfillment of the products and industrial business users' needs and stabilizing competitive position. For this reason, production systems design is regarded as important issue in global level in present era as result of rapid growth of production technologies and increase of completion in global level. Design of production systems is classified on the basis of cases such as type of product, technologies relating to machines and equipments, assembly lines balancing and leveling working stations, storage, transportation systems etc. one of the most useful type of production systems is assembly line. For this reason, main goal of the assembly lines designers is to increase efficiency of line by maximizing ratio between the obtained profit and the spent costs. Problem of balance and design of assembly lines are of the strategic activities in each production environment because lack of balance in assembly lines causes to increase cycle time and idle time and finally to decrease production rate, efficiency of line and increase system costs. For this reason, balance of assembly lines causes the production and industries specialists and engineers to raise this question that how assembly lines can be balanced and designed in the most efficient method of balance in order to ensure final quality of the product and increase benefit of the producer. Assembly lines balance problem includes assignment of tasks relating to assembly of a product to line stations in order to optimize one or more special goals. Different classifications have been presented for assembly lines by researchers in the field of industries so that each one of these classifications considers specification of these lines. Generally, we can classify assembly lines power into two groups of assembly lines. Two-sided assembly lines are used in order to produce products in large sizes such as truck and bus. Two-sided assembly lines have different advantages compared to one-sided assembly lines which are shorter lines, lower flow time and material displacement. With regard to importance of two-sided assembly lines balance. It is necessary to note that since tasks symmetry constraint has not been considered in literature of these lines, the said proposed algorithm will be presented with regard to this constraint. In this article, theoretical fundamentals of two-sided assembly lines, techniques available in literature for balancing such kind of assembly lines, tasks symmetry constraint and some concepts relating to heuristics are studied. In the second section, developed algorithm for balancing two-sided assembly lines has been introduced with regard to tasks symmetry constraint and mathematical model optimal answers have been calculated by GAMS software.Finally, efficiency of the said algorithm was compared with optimal answers obtained from mathematical model and necessary conclusions have been made in this field.

1.1 Theoretical fundamentals for two-sided assembly lines:

As referred above, we can classify assembly lines into one or two-sided assembly lines groups. Two-sided assembly lines are used in order to produce products in large sizes such as truck and bus. Two-sided assembly lines have different advantages compared to one-sided assembly lines which are shorter lines, lower flow time and material displacement. An example of these lines is shown in figure 1. In this figure, any mate of the stations is called a mated station or a status of the line and each one of the stations calls its opposite station as mate. Problem of two-sided assembly lines balance is different from one-sided assembly lines balance (simple assembly lines balance) because tasks have status constraint or constraint of preference to perform task in one of the left and right stations of assembly lines in such problems. Some tasks can be assigned to one of the line sides while some others can be assigned to each one of the line sides. Therefore, in such lines, we can classify tasks into three different groups: tasks group which can be performed in line left stations (L), tasks group which can be performed in the right stations (R) and finally tasks group which can be assigned to each one of the right or left side of the assembly line (E). For example, consider terminal assembly line relating to a truck production process. Some tasks such as installation of fuel tank and toolbox will be grouped in L type tasks group, battery assembly and exhaust storage tank will be included in group R and fastening radiator will be included in E type tasks group. Consideration of status constraints in some cases leads to inevitable idol times in some line stations. Consider two tasks i and P which are direct prerequisite of i in prerequisite relations graph of tasks P. Assume that tasks i have been assigned to one of the jth status stations of line and P is assigned to its another station in line balance. In this case, the worker relating to the station to which ith tasks have been assigned will not be able to start ith work until end of jth operations. For this reason, balance of two-sided assembly lines requires consideration of works sequence- based tasks end times.

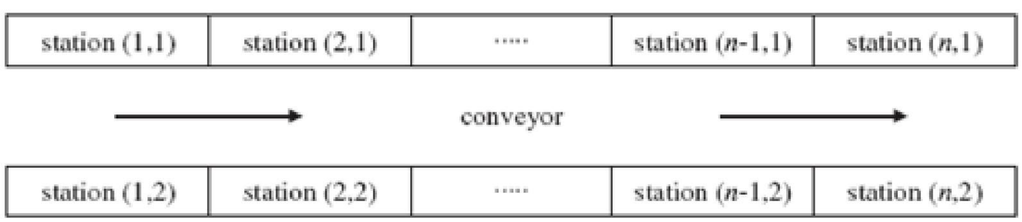


Figure 1. an example of two-sided assembly lines

2. Review of literature

Different methods have been raised for solving problem of one-sided assembly lines balance (simple). Since this problem is a subset of NP-Hard optimization problems, many researchers have tried to present heuristic solutions for solving this problem which include works performed by Talbot et al, Ghosh and Gognon. In spite of widespread literature about one-sided assembly lines problem, little attention has been paid to two-sided assembly lines balance problems solution. Barthodi introduced two-sided assembly lines in his work and used simple assignment algorithm in order to solve problem of lines balance. His main goal was to compile a computer program in order to help manage a small vehicles manufacturing unit for rapid and step by step balance of vehicle assembly lines. Lee et al used tasks group assignment algorithm in order to balance two-sided assembly lines by aiming at maximizing two criteria of tasks relatedness and time interval between the related operations. Baykas oglu and Dereli used Ant Colony Algorithm in order to optimize two-sided assembly lines balance with regard to area constraint. Kim et al presented a mathematical model for two-sided assembly lines in order to minimize cycle time for fixed number of mated stations and used genetic algorithm in order to solve it. We et al presented a simple mathematical model for two-sided assembly lines balance by aiming at minimization of weighted set of the statuses number and line stations and used branch and bound algorithm in order to solve it. Ozcan and Toklu pressnted two-sided assembly lines balance problem with multiple target function as a mathematical model and used ideal mathematical model in order to solve it.

3**. heuristic processes based on priority laws**

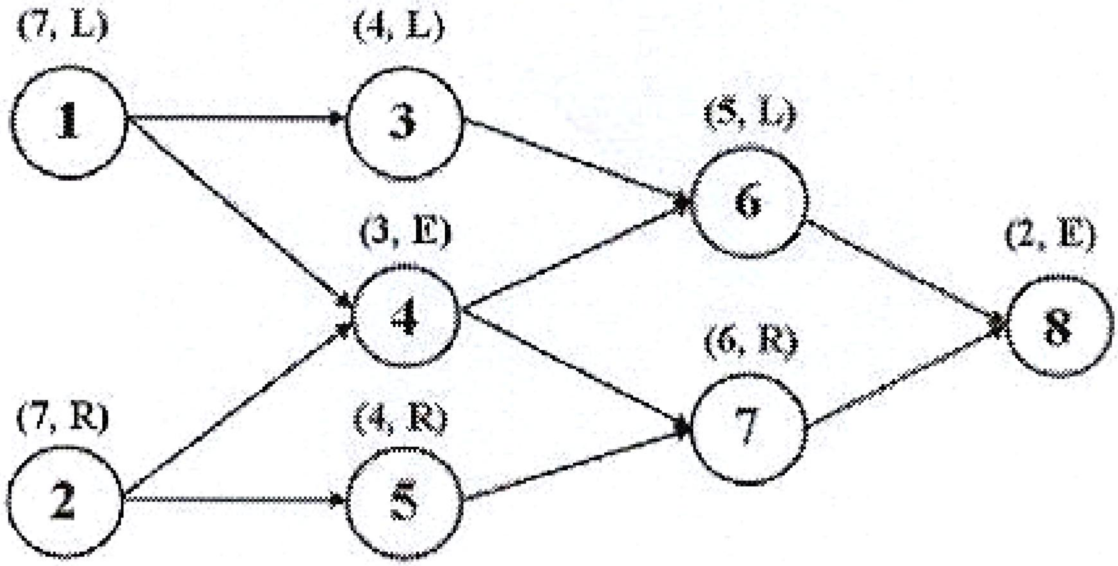
Major part of ALBP literature includes use of approximate methods for solving these problems. Generally, two classes of approximate solutions have been known for ALBP: heuristic methods and metaheuristic methods. A large part of the heuristic approaches has been presented for all kinds of simple assembly lines problem in recent decades. Heuristic processes structure was gradually developed until some processes such as tabu search technique, genetic algorithm and the liken focus on search methods in order to achieve optimal solution in the present decade and led to some techniques which are called metaheuristic methods. But we dare to say that many heuristic processes and approaches are based on priority laws in which the number of prerequisite and post-requisite and tasks processing time will be basis for selection of operations. Among different laws which have been used in recent decades, some are mentioned as the most efficient priority laws which are found in table 1. The heuristic algorithm introduced in the article for two-sided assembly lines balance is based on some of these priority laws.

name	priority value
MaxT	task time t_j
MaxPW	positional weight $pw_j = t_j + \sum_{h \in F_j^*} t_h$
MaxF	number of followers $\lvert F_j^* \rvert$
MaxTL	task time over latest station t_j / L_j
MaxTS	task time over slack $t_j / (L_j - E_j + 1)$
Max-CPW	cumulated positional weight $pw_j^* = t_j + \sum_{h \in F_j^*} pw_h^*$

Table 1. the most efficient priority laws

4. **two-sided assembly lines balance problem with regard to tasks symmetry constraint**

In this article, two-sided assembly lines balance has been studied with regard to tasks symmetry constraints. Target function of the problem includes minimization of the length and the number of assembly line stations by assuming cycle time as fixed. Problem constraints include prerequisite constraints, cycle time and tasks symmetry. A two-sided assembly lines balance has been presented by a prerequisite relations graph as shown in figure 2. In this figure, circles show tasks and arcs show prerequisite relations between them. Any task relates to label like (t_i,d) in which t_i is operational time of ith work and d is tasks group (L, R or E). Generally, symmetrical tasks set in two-sided assembly lines balance problems includes mate of the similar tasks with different status constraints. For example, fastening tires on the right and left side of a vehicle in final assembly line of a vehicle production process is an example of these tasks set. Although two symmetrical tasks can be assigned to different mated stations, they are mostly assigned to a status of the line in real assembly lines. One of the reasons is more regular positioning of assembly lines in terms of the tasks which can be performed in each one of the statuses belonging to assembly line. In this work, set of symmetrical tasks will be shown with symbol STS (Symmetric Tasks Set).



sy ... to
du ... ks,
pr ... er
ST ... .

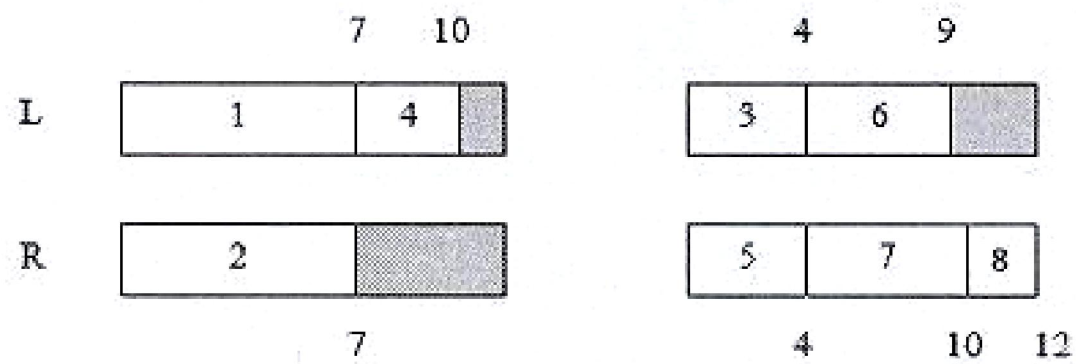


Figure 3. optimal assignment with regard to tasks symmetry constraints

As said in the previous chapters, one-sided assembly lines balance problems are classified as NP–Hard problems in terms of mathematical complexity. Two-sided assembly lines balance problem is developed form of one-sided assembly lines balance problem with this difference that tasks relating to the assembly process have preference constraints for performance in one of the right or left side stations of the assembly line. Therefore, this problem has double complexity due to status constraints on the problem in addition to complexity of one-sided assembly lines balance problem. Considering symmetry constraints of the tasks imposes another complexity on two-sided assembly lines balance problem. For this reason, two-sided assembly lines balance problem is certainly NP–Hard with regard to symmetry constraints.

5. Proposed algorithm

Two-sided assembly lines balance problem can be classified as NP–Hard combinatory problems for two reasons : firstly, tasks relating to assembly process have performance preference constraints in one of the right or left stations of assembly line(status constraints), secondly, considering tasks symmetry constraints impose another complexity on two-sided assembly lines balance problem . In this regard, use of final methods is very time-consuming and even it will be impossible for real problems. For this reason, many efforts have been made to find approximate methods which can give answers with relative quality and at reasonable time. One of the methods which have been presented for solving problems of assembly lines balance problems which is subset of such problems is heuristic approach. These approaches give for the problems relatively good answers in short time. Since two-sided assembly lines balance problem is NP–Hard with regard to tasks symmetry constraints. In this work, we try to present a heuristic approach for solving it. The proposed algorithm has been composed of six main stages:

1- In the first stage, a primary mated station is opened.
2- In the second stage, set of the tasks which is present in mated station with regard to prerequisite constraints and cycle time assigned to the mated station is determined.
3- In the third stage, tasks symmetry constraints are imposed on set of the tasks obtained from the second stage and the tasks of which symmetry is not available in set are excluded from the accessible tasks set.
4- In the fourth stage, in case that no task is assigned to the present mated station with regard to the problem constraints, new mated station is opened and the algorithm returns to the second stage, otherwise, it will go to the fifth stage.
5- In the fifth stage, some tasks are selected among set of the accessible tasks by a set of heuristic rules.
6- In the sixth stage, the tasks are selected and its symmetric tasks are assigned to the mated station if available. In order to reach the problem answer, set of the above stages should be repeated until assignment of all tasks.
7- Below is program code as programming language C++:

```
Step 1: Position=1;
While (Exist unassigned tasks) {
    Step 2: Identify a set F whose elements are such
                tasks that can be assigned to the
                current mated station.

    Step3: Remove such tasks from the set F whose
                symmetric tasks are not available.
    Step 4: If (F = Ø)
                Position = Position + 1
    Else
    Step 5: Select a task from the F list using Heuristic
                rules.
    Step 6: Assign the selected tasks and its symmetric
                task, if there is, to the current mated
                station.
```

In this program, tasks symmetry constraints are imposed by deleting tasks of which symmetries are not accessible.

Performance of this process leads to assignment of the related tasks and their symmetry to the next mated stations.

5.1 selection and assignment

Since each task belonging to the set of the accessible tasks can be assigned to the present mated station, the two following rules are applied for selection among this set:

1- Selection of the task which has the highest rank (weight) according to a heuristic method. In the present article, tasks rank has been calculated on the basis of one of three heuristic methods of MAXPW, MAXT or MAXF(it is necessary to note that the proposed algorithm has been written in three separate ranks by three heuristics and the results obtained from application of these heuristics have been compared with each other).
- MAX PW: according to this method, weight of each element equals to element performance time plus post-requisite elements performance time
- MAX T: on the basis of this method, weight of each element equals to element performance time
- MAX F: weight of each element in this method equals to the number of direct post-requisite of that element according to the Precedence diagram

2- In case of two or more similar cases, the tasks which have the smallest task number are selected. Since tasks are numbered by order in assembly lines balance problems, use of this rule leads to more regular assignment of tasks because the tasks which have lower task number will be assigned to the more primary stations.
3- Selected tasks should be assigned by the above rules to one of the right or left stations of the present mated station with regard to the status constraints. For this purpose, in case that the

selected tasks belong to tasks group type L or R, they are assigned to the related station and in case of symmetric tasks; they are assigned to the related station. In case that selected tasks are among the tasks group type E, the following rules are used to select one of two right or left stations:

4- Selection of the station in which selected tasks can have smallest starting time.
5- Selection of the station in which selected tasks assignment leads to shorter inevitable idol times.
6- Random selection of one of the stations

Rule 1 will give priority to the stations which have less operational load and efficiency of the line will increase. Improvement of the line efficiency criterion is not only necessary for minimizing the number of stations and line length but also for decreasing the probability of creating inevitable idol times.

Rule 2 is applied in case that starting time of the selected tasks in both stations is equal. In this case, the station of which selected tasks assignment leads to shorter inevitable idol times will be selected.

5.2 heuristic algorithm process

In this section, we intend to study function of the introduced heuristic algorithm in section 5 for hypothetical precedence graph No. 2. The above algorithm process is found in table 2 and according to the steps mentioned in section 3. Assessment of the above table shows that application of the introduced algorithm for the hypothetical precedence graph No. 2 leads to assignment of the activities as 2 workstations. It is necessary to note that the applied assignment process applied in this heuristic algorithm includes 12 units with regard to tasks symmetry constraint and cycle time.

Table 2: heuristic algorithm process for hypothetical precedence graph No. 2

stages	step 1	step 2	step 3	step 4	step 5	step 6
1	**first position**	**F={1,2}**	**F*={1,2}**		**selection of task 1 according to rule 2**	**assignment of task 1 to the left station and task 2 to the right station**
2	**-**	**F={3,4,5}**	**F*={3,4,5}**	_	**selection of task 4 according to rule 1**	**assignment of task 4 to the right station according to random assignment rule 3**
3	_	**F={3}**	**F*={}**	**second position**	_	_
4	_	**F={3,5}**	**F*={3,5}**	_	**selection of task 5 according to rule 1**	**assignment of task 5 to the right station and task 3 to the left station**
5	_	**F={6,7}**	**F*={6,7}**	_	**selection of task 7 according to rule 1**	**assignment of task 7 to the right station and task 6 to the left station**
6	_	**F={8}**	**F*={8}**	_	**task 8**	**assignment of task 8 to the right station**

- F={set of assigned tasks}
- F*={set of assigned tasks after deleting the tasks of which symmetries are not available}

6. Numerical calculations

In this section, the proposed heuristic algorithm has been applied in section 5 for P24 problems in work of kim et al [13] and P65 problem in work of lee et al [14]. It is necessary to note that symmetrical tasks are not specified in any problems and set of symmetric tasks has been determined as shown in table 2. It is necessary to note that the mentioned algorithm for the said experimental problems has been calculated separately with three heuristic techniques.

Table 3: set of determined symmetric tasks for experimental problems

Problem	Symmetric task sets
P24	STS={(1,4) (2,3) (5,7) (11,15)(16,20)}
P65	STS={(8,10) (39,40) (44,45)(51,53)}

6.1 calculation results

Table 4: numerical example calculation results

Problem	Cycle time	Heuristic1 MAX RPW	Heuristic 2 MAX LC	Heuristic3 MAX TF
P24	18	5[9]	5[10]	5[9]
	20	5[10]	4[8]	5[9]
	25	4[7]	4[7]	4[7]
	30	3[6]	3[6]	3[6]
P65	381	7[14]	7[14]	7[14]
	490	6[12]	6[11]	6[12]
	544	5[10]	5[10]	5[9]

❖ It is necessary to note that number inside the bracket shows the number of individual stations and the number beside the bracket shows the number of mated stations.

6.2 conclusion:

Many algorithms and solutions have been presented in order to solve one-sided assembly lies balance problem but little attention has been paid to the two-sided assembly lines balance. This may be due to calculation complexity in two-sided assembly lines balance problem because this problem is contrary to the assembly lines.

Table 5: the results obtained from comparison of the proposed algorithm function for solving two-sided assembly lines balance problem and results obtained from integer model solution

Problem	Cycle time	MIP (With symmetric constraints)	MIP (without symmetric constraints)	Heuristic1 MAX T	Heuristic 2 MAX PW	Heuristic3 MAX F
P24	18	5[10]	5[9]	5[9]	5[10]	5[9]
	20	4[8]	4[8]	5[10]	4[8]	5[9]
	25	4[8]	4[8]	4[7]	4[7]	4[7]
	30	3[6]	3[6]	3[6]	3[6]	3[6]
P65	381	-	-	7[14]	7[14]	7[14]
	490	-	-	6[12]	6[11]	6[12]
	544	-	-	5[10]	5[10]	5[9]

One-sided assembly lines balance problem requires considering works sequence- based tasks ending times. In this research, two-sided assembly lines problem has been studied with regard to tasks symmetry constraints. Since this problem belongs to the group of combinatory problems with NP-Hard complexity, algorithm based on heuristic rules has been introduced in order to solve it and its ability to solve the experimental problems was studied. It is necessary to note that there are no experimental problems with tasks symmetry constraint in the available literature. For this reason, some required constraints have been added to some experimental problems in order to test heuristic algorithm to be used for testing the algorithm. We study results obtained from this research:

fficiency of the developed heuristic algorithm (research main goal)

Numerical tests show that the proposed algorithm is more efficient than the mathematical model. In addition, table 4 shows that the mathematical model is not able to solve the problems with large size while the proposed algorithm is used for solving problems with real sizes. This algorithm produces some answers with acceptable error compared to optimal answer n very short time (at most 4 seconds).
Comparison of three heuristics MAX PW, MAX LC, MAX TF in heuristic algorithm

As said before, three heuristic techniques applied in heuristic algorithm are among the most efficient heuristics. Study of table 4 confirms this fact mentioned in assembly lines literature and these techniques have equal result and efficiency so that this holds true for results obtained from application of the heuristic algorithm.

7. Future researches

This research can be generalised in some fields and can be regarded as a ground for the future research. Firstly, only mated and individual stations minimisation criterion has been used in order to assess the problem and considering other criteria such as balancing criterion and levelling the operational load of the stations and generalisation of problem to multi-objective optimisation problem can be a ground for other researches. Secondly, case study of this field especially in final assembly lines relating to production of bus and truck and other heavy facilities are good ground for the researches.

References

[1]. Mozafar, Abbas, Akbari Jokar, Mohamamd Reza, types of assembly lines balancing problems, Sanaye Magazine, No. 2, P 23, Winter 1993

[2]. Soleiman Pour, Maghsoud, Zeinal Zadeh, Amin, application of a mathematical model for balancing assembly line ; case study, Farasooye Modiriat Press, No. 11, P7-30, winter 2010

[3]. Taghi Zadeh, Hoshang, Zeinal Zadeh, Amin, application of weighted priority heuristic methods and the longest task time (LCR)for balancing assembly lines and its effect on performance of the organization : case study: Industrial Engineering and Production Management International Press, No. 3, Vol. 20, P 55-64, fall 2009

[4]. Seyed Hosseini, Seyed Mohammad, Plant Management, Tehran: Universities Humanities Book Compilation And Study Organization (Samt), Edition 6, 2001

[5]. Motaghi, Hayedeh, production and operations management, Tehran : Avaye Patrice Press, Edition 2, 2005. **http://www.bahrevari.ir**

[6]. Boysen N., Fldner M., Scholl A. (2007), " A classification of assembly line balancing problems ", European Journal of operational Research, Vol. 183, Issue 2, pp. 674-693

[7]. Scholl A ., Becker C. (2006), " State – of – the - art exact and heuristic solution procedures for simple assembly line balancing", European Journal of Operational Research, Vol. 168, Issue 3, pp. 666-693.

[8]. Bartholdi JJ . (1993)," Balancing two- sided assembly lines : a case study" . Int J Prod Res 31(10):2447_2461.

[9]. Baker C., Scholl A.(2006)," A survey on problems and methods in generalized assembly line balancing ", European Journal of operational Research,168,694- 715.

[10]. Ghosh S., Gagnon R.J.(1989)," A comprehensive literature review and analysis of the design, balancing and scheduling of assembly systems. International Journal of Production Reaserch,27,637- 670.

[11]. Ozcan U., toklu B (2009).," Balancing of mixed- model two- sided assembly lines",Computers and International 57,217-227.

[12]. Kim YK., Kim Y, Kim YJ (2000)," Two-sided assembly line balancing : a genetic algorithm approach", Prod Plan Control 11(1):44- 53.
[13]. Lee To, Kim YK (2001),"Two- sided assembly line balancing to maximize work relatedness and slackness." Comput Ind Eng 40(3):273- 292.
[14]. Talbot FB, Patterson JH, Geherlin WV(1986)," A comparative evaluation of heuristic line balancing techniques." Management Science, 32: 430- 54
[15]. Wu E, Jin Y, Bao J, Hu X.(2007)," A branch – and – bound algorithm for two – sided assembly line balancing.Int J Adv Manuf Technol DoI 101007/00170-007-1286-3.
[16]. Baykasglu A,Dereli T (2006)," Two- sided assembly line balancing using an ant- colony-based heuristic." Int J Adv Manuf Technol 36 : 582- 588.
[17]. Erel E and Serin,S (1998),"A survey of assembly line balancing procedures."Production Planing and Control,9,414-434.
[18]. Bukchin, J., Dar- El, E.M.,Rubinovitz,J., (1997),"Team oriented assembly system design: A new approach." International Journal of Production Economics 51,47-57.
[19]. Bukchin, J., Dar- El, E.M., Rubinovitz, J., (2002)," Mixed-Model assembly line design in a make-to-order environment."Cumputers and International Engineering 41,405-421.
[20]. Baykasoglu,A.,Ozbakir,L.,(2006)."Stochastic U-line balancing using genetic algorithms."International Journal of Advanced Manufacturing Technology.1007/s00170-005-0322-4.
[21]. Buxey, G.M.,(1974)."Assembly line balancing with multiple station."Management Science 20,1010-1021.
[22]. Dolgui, A., Ihnatsenka,I.,(2004)."Branch and bound algorithm for optimal design of transfer lines with multi-spindle stations."Ecole National Suoerieure des Mines,Sain.
[23]. Gershwin,S.,2000."Design and operation of manufacturing systems: The control-point policy."IIE Transaction 32,891-906.
[24]. Gadidov, R.., Wilhem, W., (2000). "A cutting plane approach for the single-product assembly system design problem. "International Journal of production Research 38,1731-1754.
[25]. Dar-El.E.M.,Rabinovitch,M.,(1988)."Optimal planning and scheduling of assembly lines. "International Journal of Operational Research 26,1433-1450.
[26]. Chiang,W.C.,Urban.T.L.,(2002)."A hybrid heuristic for the stochastic U-line balancing problem", Working paper, University of Tulsa, Oklahoma,UAS.
[27]. Dolgui,A., Guschinsky,N.,Levin,G.,(2001)."A mixed integer program for balancing of transfer line with grouped operations." IN: Proceeding of the International Conference on computer and Industrial Engineering, Florida,USA,2001 pp.541-547.
[28]. Gokcen, H., Agpak, K., (2006). "A goal programming approach to simple U-line balancing problem." European Journal of Operational Research 171,577-585.
[29]. Gokcen,H.,Agpak,K.,Gencer,C.,Kizilkaya, E., (2005). "A shortest rout formulation of simple U-type assembly line balancing problem." Applied Mathematical Modeling 29,373-380.
[30]. Johnson, R.V.,(1983)."A branch and bound algorithm for assembly line balancing problem with formulation irregularities", Management Science 29,1309-1324.
[31]. Johnson, R.V.,(1991)."Balancing assembly lines for teams and work groups."International Journal of Production Research 29,1205-1214.
[32]. Kao,E.P.C.,(1976)."A preference order dynamic program for stochastic assembly line balancing." Management Science 22,1097-1104.
[33]. Kim.H.,Park,S.,(1995)."A strong cutting plane algorithm for the robotic assembly line balancing problem." International Journal of Production Research 33,2311-2323.
[34]. Kim Y.K.,Kim,J.Y.,Kim,Y.,(200b)."A co-evolutionary algorithm for balancing and sequencing in mixed model assembly lines."Applied Intelligence 13,247-258.
[35]. Kim,Y.K.,Kim,S.J.,Kim,J.Y.,(2000c)."Balancing and sequencing mixed-model U-lines with a co-evolutionary algorithm."Production Planning and Control 11,754-764.
[36]. Macaskill,J.L.C.,(1972)."Production-line balances for mixed model lines."
[37]. Malakooti, B.,(1994)."Assembly line balancing with buffers by multiple criteria optimization." International Journal of production Research 32,2159-2178.

[38]. Mather,H.,(1989).”A heuristic for solving mixed-model line balancing problems with stochastic task duration and parallel station.” International Journal of production Economics 51,177-190.

[39]. Pinnoi,A., Wilhelm,W.E,(1997).”A family of hierarchical models for assembly system design.” International Journal of production Research 35,253-280.

[40]. Rosenberg, O., Ziegler, H.,(1992).”A comparison of heuristic algorithm for cost-oriented Assembly line balancing .” Zeitschrift fur production Research 36,477-495.

[41]. Sabuncuoglu,I.,Bukchin, J.,(1993).”RALB-A heuristic algorithm for design and balancing for robotic assembly lines .”Annals of the CIRP 42,497-500.

[42]. Salvson,M.E.,(1995).”The assembly line balancing problem.”The Journal of Industrial Engineering 6(3),18-25.

[43]. Sarin,SC.,Erel,E.,Dar-El,E.M.,(1999).”A methodology for solving single-model, stochastic assembly line balancing problem.”Omega 27,525-535.

[44]. Urban, T.L.,(1998).”Optimal balancing of U-shaped assembly lines.” Management Science 44,738-741.

[45]. Wilhem,W.E.,(1999).”A column-generation approach for the assembly systems design problem with tool changes.” International Journal of Flexible Manufacturing Systems 11,177-205.

[46]. Sparling, D.,(1998). ”Balancing JIT production units : The N U-line balancing problem.” International Systems and Operational Research 36,458-501.

[47]. Sparling, D., Miltenburg, J., (1998). ”The mixed-model U-line balancing problem .” International Journal of production Research 36, 458-501.

[48]. Suer, G.A., (1998). ”Designing parallel assembly lines.”Computers and Industrial Engineering 35,467-470.

1/25/2022