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Minimizing Number of Stations and Cycle Time for Mixed Model Assembly Line

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***Abstract*— Assembly Line Balancing is one of the widely used basic principles in production system. The problem of Assembly Line Balancing is distribution of activities among the workstations so that there will be maximum utilization of human resources and facilities without disturbing the work sequence. The specified objective for the work is to minimize number of stations and cycle time, subject to precedence constraints. In this work, the single model assembly line problem or equivalent model of multi model assembly line problem are solved for minimum number of stations and minimum cycle time. The work carried has the objective to minimize cycle time and the work stations. For deriving the minimize number of stations and cycle time the method is divided into two stages.1) Optimize the number of work stations. 2) Optimize the cycle time. The problem is chosen based on the presence of complexity and the number of models that are assembled on the line. This is a seat fabrication and assembly and has 28 activities for 04 different models.**

Keywords*— Assembly line, line optimization, minimizing number of stations, time of each station.

I. INTRODUCTION

The assembly line balancing is to assign the different tasks to various stations such that the precedence relations are maintained and some measurements of effectiveness are being optimized. The main objective of LB is to distribute the required tasks evenly over the work station by minimizing the time of the machines and the operators.

In today's world, some main purposes in order to be successful. These main purposes are; raising the level of productivity, efficiency, increasing capacity, improving quality, providing customer requests and satisfaction, using labor, machine and equipment effectively and providing ergonomic work environment.

The process in which the number of parts of a product is combined in according to a predetermined sequence is called an assembly line.

The first published paper of the assembly line balancing problem (ALBP) was made by Salve son (1955) [1] who suggested a linear programming solution. Since then, the topic of line balancing has been of great interest to researchers. However, since the ALB problem falls into the NP hard class of combinatorial optimization problems (Gutjahr and Nemhauser, 1964) [2] it has consistently developed the efficient algorithms for obtaining optimal solutions.

During the assembly line process the product traverses in a assembly line, station by station, while in each workstation a fixed predetermined set of tasks is performed. Each task is an atomic working unit, which usually requires specific machinery and skill. The assembly line design involves the assignment of these tasks into the work- stations, subject to given precedence relationships among the tasks.

II CLASSIFICATION AND DESCRIPTION OF ASSEMBLY LINE BALANCING PROBLEM

Generally the assembly line is carried out in many industries. Especially, they are used to produce consumer goods such as cars, engines, domestic appliances, television sets, computers and other electrical appliances. These products are rather different, and it is necessary to implement different production systems.

A) Single - model lines:

In single model assembly line the same products are continuously manufactured in large quantities. According to Merengo. Nava & Pozzetti (1999), single model lines are "suitable for large-scale production. In this line no operation changes are carried out at any station and all the stations repeat the same work. Thus, does not change in workloads of stations.

B) Mixed - model lines :

In this line system can produce the production sequentially by mixing more than one product on the same line. Product ranges produces on the same line are quiet similar to the main product. According to Merengo, Nava & Pozzetti (1999), "it is possible to produce very small batches (even one – unit batches.)." (s. 2836). Also whenever we required to change the model on the line, set-up is carried out quite fast and cheap. For example, if option differences of main product are produced sequentially mixed on the same line according to customer demand, this belongs to mixed-model assembly lines class.

C) Multi - model lines:

In this line the similar products with differences in production processes are produced on these lines. Due to differences in production processes, because of situations like operation processing times, ergonomic need of work space and so on, products are produced in batches. Even a lengthy set-up study is needed during product change.

III OBJECTIVE

a) To develop the algorithm for Optimizing the MMALBP
b) To minimize the number of stations.
c) To optimize the cycle time.

IV LITERATURE SURVEY

- Erel and Gökcen (1999) are studied THE balancing problem with the shortest-route formulation by turning mixed-model assembly lines into single model assembly lines.
  In order to meet the customer satisfaction, and also to get high volume and variety of products, mixed-model assembly lines are examined within the scope of even this study. Creation of task sets of each model, performance time measurement of tasks, considering precedence relations are quite difficult. It is assumed that each model has common tasks to avoid this situation in this study.

- Matanachai and Yano (2001) have balanced mixed-model assembly lines, in order to reduce workload of work stations. Therefore a heuristic solution procedure based on filtered beam search is developed. Their focus is an assigning task to stations so that workloads are reasonably well balanced and it is relatively easy to construct daily sequences of jobs that provide stable workloads (in a minute to minute sense) on the assembly line. Stability provides to contribute to the quality of the product by the fact that employees working without having to rush. For it, they focused on closed-station, paced lines with Fixed-Rate Launching (FRL) on structure of the line.

- Jin and Wu (2002) tried to balance mixed-model assembly lines by taking advantage of goal chasing method and using good parts in early sequence. A heuristic method called „variance algorithm" is used for this. In just in time systems, a simple heuristic method called goal chasing method can be used in problem solving. Since the objective function is different within the scope of this problem, the algorithm has been revised without changing the impact of basic point. The goal chasing method is very simple and large scale problems can be solved with a small amount of time, regardless of the number of parts, models or demand.

- Esmaeilian, Ismail, Sulaiman, Ahmad and Hamedi (2009) focus on assigning and balancing of tasks to workstations as long as target purposes are provided. Mixed model production balancing problem usually is transformed into a single model line-balancing problem to solve. But in this study, mixed-model problem has not been turned into single-model problem, and the settlement has been done by arranging it as mixed products on the parallel assembly lines.
- Yağmahan (2011) focused on balancing mixed-model assembly lines by using multi-objective ant colony optimization approach.
  This study considers the aim to minimize smoothness index and the balance delay for the cycle time given in mixed-model assembly lines. The multi-objective ant colony optimization algorithm is used in the solution of this problem
  algorithm is given in the final balancing. After that, model sequencing is used to reduce the impact of rest unbalanced models. Model imbalance is measured
  by comparing targeted times and required times for stations

V PROBLEM DEFINITION

The main objective of our problem is minimizing the number of workstations and cycle time associated with ALBP. The problem is chosen based on the presence of complexity and the number of models that are assembled on the line. This is a seat fabrication and assembly and has 28 tasks for 04 different models. The precedence relationship table is presented in table-1. The one value in the row represents the precedence relation with respect to the respective activity. It gives four different times as given in table-1.The algorithms and the computer codes developed are applied to an assembly line which is presently used in an automobile industry. The main purpose of our work is assignment of tasks of mixed models to different stations; this problem is considered for optimizing cycle time and number of work stations.

VI ALGORITHM DEVELOPED FOR SOLVING ASSEMBLY LINE BALANCING PROBLEM

Algorithm is developed for Optimizing the Number of work stations and cycle time for the ALBP problem. The Objectives which were discussed were effectively achieved during the simulation. By running the algorithm the feasible solution were obtained by varying number of stations.

For equivalent single models, the algorithm is defined below. The algorithm delivers number of feasible solutions.

a) Predict the average number of stations required using NOOFSTATIONS=NOOFTASKS/3

b) Round off the NOOFSTATIONS to the lower integer.

c) Assign a new station STATION[1] with a cycle time T = MINCYCLETIME

d) Determine all the tasks that do not have the predecessor TASKSWOPRED = { i, j,…., n}

e) Assign one task in TASKSWOPRED to STATION [1]

f) Remove the tasks that is assigned to STATION [1] from the graph and update it as TASKSWOPRED = { j,k,….,n }.

g) Update the station cycle time as T = MINCYCLETIME - t_i

h) Repeat steps e to g, until T is positive and update the T and TASKSWOPRED each time.

i) When T turns negative, look for any other tasks in TASKSWOPRED to fit in STATION [1], but the T should remain positive.

j) When T turns zero or negative for all the tasks in TASKSWOPRED, create a new station as STATION [2].

k) Repeat steps e to j.

l) Repeat step e to k for all feasible solutions.

m) Try the solutions for a pre-decided number of stations. If the solutions derived are not feasible, repeat e to k after update the T as MINCYCLETIME+1.

n) When all the feasible solutions are obtained, store the updated T.

o) Decrease the number of stations to 1 less than the NOOFSTATIONS and run the above procedure again.

p) Increase the number of stations to 1 more than the NOOFSTATIONS and run the above procedure again.

VII METHODOLOGY

To develop the mixed assembly line model which will reduce the number of stations and cycle time associated with it. To develop the algorithms for the model, which will result in optimal solutions for reducing number of stations and cycle time the model will be based on the Optimizing techniques. The model shall be based on Mixed Model Assembly Line Balancing Problem by applying Branch and bound based solution approach. By the applications of MATLAB the simulation can be run for the problem to generate the solutions, which will reduce the number of stations and the cycle time associated with it. By this method an optimal solution is obtained for MMALB Problem.

MALB model which aims to minimize the total cost associated with the design of the assembly line. Some of the model assumptions are as follows:

1) Multiple similar models of the same products are be assembled on the same line.

2) The task duration is differ between models.

3) A cycle time is associated with each model type.

4) The duration of a task is not longer than the cycle time of the associated model.

5) The station time of each model should not exceed the models cycle time.

6) Assume that the each task should be assigned to exactly one station in each model.

VIII PRECEDENCE DIAGRAM

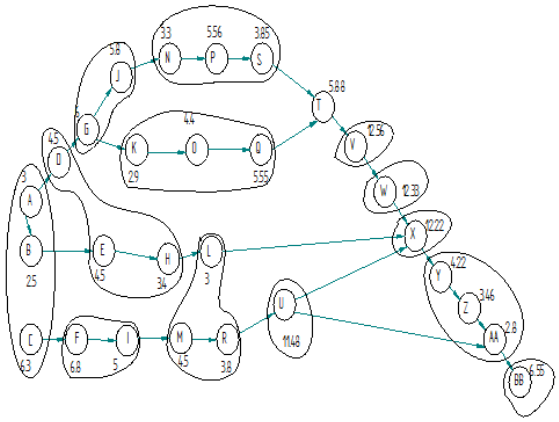

Fig-1

PRECEDENCE TABLE

Tasks	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB
A	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Z	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table-1

TASK TIME FOR INDIVIDUAL MODEL

Tasks	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Model1	2.8	2.3	6.2	4.2	4.2	6.8	5	3.2	3	5.5	2.8	2.5	4.4	3.2	4.2	5.5
Model2	2.9	2.4	6.25	4.35	4.75	7	6	3.3	4	5.7	2.7	3.5	4.5	3.1	4.4	5.4
Model3	3.1	2.7	6.35	4.75	4.35	6.5	7	3.4	6	6.1	2.9	2.5	4.1	3.4	4	5.9
Model4	3.2	2.6	6.4	4.7	4.7	6.9	6	3.7	7	5.9	3.2	3.5	5	3.5	5	5.44
Avg.time	3	2.5	6.3	4.5	4.5	6.8	6	3.4	5	5.8	2.9	3	4.5	3.3	4.4	5.56

Tasks	Q	R	S	T	U	V	W	X	Y	Z	AA	BB
Model1	5.5	3.6	3.6	5.84	11.4	12.5	12.3	12.2	4.2	3.4	2.7	6.5
Model2	5.8	3.7	3.8	5.9	11.72	12.24	12.5	12.1	4.1	3.3	2.6	6.6
Model3	5.8	3.8	3.9	5.94	11.35	12.7	12.4	12.3	4.36	3.5	2.9	6.8
Model4	5.1	4.1	4.1	5.84	11.45	12.8	12.12	12.28	4.22	3.64	3	6.3
Avg.time	5.55	3.8	3.85	5.88	11.48	12.56	12.33	12.22	4.22	3.46	2.8	6.55

Table-2

By entering the above data's i,e precedence table, task time and tasks time for individual model in the MATLAB 2012 we have got the following results.

IX RESULTS

1)Number of Station=12
maxStation =12
nom =4
not =28
tw =Columns 1 through 13
3 3 7 5 5 7 6 4 5 6 3 3 5
Columns 14 through 26
4 5 6 6 4 4 6 12 13 13 13 5 4
Columns 27 through 28
3 7
max_tw =13
cmin =13
ctMin =13
station =
1 4 7 5
2 5 11 15
3 10 14 12
6 8 9 15
13 17 18 18
12 21 20 19
16 19 20 0
22 21 0 0
23 21 0 0
24 0 0 0
25 26 27 0
28 0 0 0
station_count =
4 4 4 4 4 4 3
2 2 1 3 1
station_time =
19
16
20
21
19
25
16
25
25
13
12
7
num_of_sols =43

station_times_all =Columns 1 through 13
14 14 14 14 20 15 15 19 16 24 24 20 24
16 19 16 20 16 20 19 16 24 16 19 21 16
16 16 21 20 17 20 20 26 16 16 21 18 17
16 22 16 20 26 25 20 17 18 18 17 18 17
17 20 20 19 19 17 24 19 21 21 21 17 26
15 14 19 15 15 16 17 22 22 22 17 20 20
12 16 16 23 16 16 16 16 23 23 16 25 16
13 13 13 16 26 26 26 26 26 26 26 16 26
16 16 26 16 25 25 25 25 16 16 16 25 26
13 13 13 13 13 13 13 13 13 13 13 13 13
12 12 12 12 12 12 12 12 12 12 12 12 12
7 7 7 7 7 7 7 7 7 7 7 7 7
Columns 14 through 26
24 20 20 16 19 25 16 20 24 20 20 24 15
19 20 21 25 17 16 20 20 16 15 18 16 19
21 17 18 16 19 19 19 19 18 19 17 21 21
17 18 17 21 21 17 20 24 20 19 19 18 20
20 21 21 20 19 25 21 16 17 20 26 20 20
19 20 19 26 20 18 18 19 27 26 19 18 20
16 22 30 16 23 16 23 16 16 16 16 22 31
26 26 26 26 26 26 26 26 26 26 26 26 26
16 16 16 26 16 25 16 25 16 26 26 16 16
13 13 13 13 13 13 13 13 13 13 13 13 13
12 12 12 12 12 12 12 12 12 12 12 12 12
7 7 7 7 7 7 7 7 7 7 7 7 7
Columns 27 through 39
23 23 19 19 18 24 17 25 25 25 25 25 16
16 16 20 20 16 16 17 16 16 16 16 16 16
20 19 19 20 24 16 19 16 22 22 22 18 18
19 17 19 21 21 21 20 21 17 17 19 16 21
19 20 20 16 19 19 20 19 19 19 18 20 24
19 26 26 26 19 20 26 26 19 19 18 20 20
22 16 16 16 23 23 16 16 16 16 16 23 23
26 26 26 26 16 26 26 26 26 26 26 26 16
16 26 16 26 16 16 25 25 25 16 16 16 25
13 13 13 13 13 13 13 13 13 13 13 13 13
12 12 12 12 12 12 12 12 12 12 12 12 12
7 7 7 7 7 7 7 7 7 7 7 7 7
Columns 40 through 43
24 24 16 19
16 16 21 16
24 18 17 20
19 17 21 21
20 24 19 19
20 20 20 25
14 16 23 16
25 25 25 25
16 26 16 25
13 13 13 13
12 12 12 12
7 7 7 7
station_total_time =Columns 1 through 13
167 182 193 195 212 212 214 218 214 214
209 212 220
Columns 14 through 26
210 212 220 224 212 219 211 217 212 219
219 213 220
Columns 27 through 39

212 221 213 222 204 213 218 222 217 208
208 212 211
Columns 40 through 43
210 218 210 218

2)Number of station =13
nom =4
not =28
tw =Columns 1 through 13
3 3 7 5 5 7 6 4 5 6 3 3 5
Columns 14 through 26
4 5 6 6 4 4 6 12 13 13 13 5 4
Columns 27 through 28
3 7
max_tw =13
cmin =12
ctMin =13
sationInfo =Columns 1 through 13

2	4	1	3	5	1	3	7	2	4	3	7	2
3	3	1	4	3	1	4	3	2	6	4	6	2
2	3	1	2	3	1	3	8	2	4	4	8	5
2	3	1	2	6	1	3	7	2	4	6	8	3

Columns 14 through 26

5	4	6	5	6	6	7	10	8	9	11	12	12
7	6	7	8	2	7	8	5	9	10	11	12	12
5	4	6	5	6	6	8	7	9	10	11	12	12
4	7	6	7	4	8	8	5	9	10	11	12	12

Columns 27 through 28

12	13
12	13
12	13
12	13

num_of_sols =4
num_of_tasks =28
loadInfo =
Columns 1 through 13

3	3	1	1	3	2	2	2	1	1	3	3	2
1	2	1	1	3	2	2	4	1	1	3	3	2
2	1	1	3	2	2	3	2	1	1	2	3	3
2	2	1	3	1	2	1	1	1	2	2	2	3

Columns 14 through 26

1	2	1	2	3	2	1	1	1	1	1	1	2
1	2	2	1	3	3	2	1	1	1	1	1	2
2	3	2	1	1	3	1	1	1	1	1	1	2
3	2	3	3	1	1	3	1	1	1	1	1	2

Columns 27 through 28

3	1
3	1
3	1
3	1

station =

3	6	0	0
1	4	9	0
2	7	13	8
10	14	18	0
21	14	17	0
5	11	16	0
8	15	17	0
12	19	20	0
22	0	0	0
23	0	0	0
24	0	0	0
25	26	27	0
28	0	0	0

station_count =
2 3 4 3 3 3 3
3 1 1 1 3 1
station_time =
14
13
18
14
22
14
15
13
13
13
13
12
7
num_of_sols =4
station_times_all =

14	14	14	14
13	14	13	13
14	15	18	18
14	14	14	14
15	22	15	22
14	14	14	14
13	14	22	15
13	12	13	13
13	13	13	13
12	13	13	13
13	13	13	13
12	12	12	12
7	7	7	7

station_total_time =
167 177 181 181

If we continue for further experiment the cycle time remains same. So the optimum number of stations is 12 and cycle time is 13minutes, hence no need to increase the number of stations, so by increasing the number of stations simply we are wasting the cycle time, expenditure, man power etc.

X CONCLUSION

In this study, we have developed the algorithm for mixed Model assembly line which will reduce the number of stations and cycle time associated with it. We have developed the algorithms for 28tasks and 4 models models, which will result in optimal solutions for reducing number of stations and cycle time based on the Optimizing techniques. By the applications of MATLAB we have generated the simulation for the solution, which will reduce the number of stations and the cycle time associated with it. By running the MATLAB algorithm we have calculated the cycle time by varying the number of stations. For station 10 the cycle time is 16minutes, for station 11 the cycle time is 15minutes, for station 12 the cycle time is 13minutes, for station 13 the cycle time is 13minutes.if we increase the number of stations then also we have got the same time, so based on the results the stations 12 and 13 the cycle time is same, so the optimum number of stations is 12 and cycle time is 13minutes.

From the above calculated result we can concluded that the minimum number of station is 12 and cycle time is 13minutes for the selected problem.

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