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01.	D.N. Dian Retno Sari Dewi P., ST., MT.	531.97.0298

Tugas : Sebagai peserta Seminar *The 14th International Conference on QIR* dengan judul *"Production Assembly Line Balancing by Considering the Perfomance Rating of The Operator"*

Waktu : Senin – Kamis, 10 -12 Agustus 2015

Tempat : Lombok Raya Hotel
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Lain-lain : Biaya diambilkan dari anggaran Fakultas Teknik tahun 2014/2015 dengan kode 602.02.2233 dan 601.02.2233

Demikian Surat Tugas ini diterbitkan, harap dilaksanakan dengan sebaik-baiknya dan memberikan laporan setelah selesai melaksanakan tugas.

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PROGRAM AT GLANCE

Date	Time	Program	Venue
10 August 2015	04.00-06.00 pm	Registration and Welcome Drink	Pre-function Hall
11 August 2015	07.30-08.00 am	Registration	Pre-function Hall
	08.00-08.40 am	Opening Ceremony	Rinjani Room I, II, III
	08.40-09.00 am	Photo Session	
	09.00-09.30 am	Keynote Speech 1	
	09.30-10.30 am	Talk show: Serve the Country	
	10.30-10.45 am	Coffee break	
	10.45-12.00 am	Keynote Speech 2 and 3	
	12.00-01.00 pm	Lunch	Restaurant
		Poster Session	Pre-function Hall
		Exhibition	
	01.00-03.00 pm	Parallel session	Meeting Rooms
	03.00-03.30 pm	Coffee Break	Pre-function Hall
		Poster Session	
		Exhibition	
	03.30-05.00 pm	Parallel session	Meeting Rooms
	05.00-07.00 pm	Poster Session	Pre-function Hall
		Exhibition	
	07.00-09.00 pm	Banquette Dinner	Rinjani Room I, II, III
12 August 2015	08.00-10.00 am	Parallel session	Meeting Rooms
	10.00-10.30 am	Coffee Break	Pre-function Hall
		Poster Session	
		Exhibition	
	10.30-12.00 am	Parallel session	Meeting Rooms
	12.00-01.00 pm	Lunch	Restaurant
		Poster Session	Pre-function Hall
		Exhibition	
	01.00-03.00 pm	Parallel session	Meeting Rooms
	03.00-03.30 pm	Coffee Break	Pre-function Hall
		Poster Session	
		Exhibition	
	03.30-05.00 pm	Parallel session	Meeting Rooms
	05.00 - 06.00 pm	Closing Ceremony	Selaparang Room
13 August 2015	08.00 am-08.00 pm	Social Tour Lombok	

Production Assembly Line Balancing by considering the Performance Rating of the Operator

Dian Retno S. Dewi[1,a], and Martinus Edy Sianto[1,b]

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Keywords: Assembly line balancing; Total cost; Optimization

Abstract. Line and work cell balancing is an effectual instrument to develop the throughput of assembly lines and work cells while reducing manpower requirements and costs. Assembly Line Balancing is the problem of conveying operations to workstations along an assembly line, in such a way that the assignment be optimal in some sense. Our system was designed to minimize the number of workstations, operators and cycle time as well as considering operator performance rating. The models will be developed from the Elsayed and Lesmana model to minimize the cost of work stations, cycle cost, labor cost and the cost of idle labor.

Introduction

The manufacturing assembly line balancing was introduced in the early 1900. It was designed to be an efficient, highly productive way of manufacturing a particular product [1]. An assembly line is a flow oriented production system where the productive performing the operations, referred to as stations, are associated in a serial manner. The workpiece visit stations successively as they are moved along the line usually by some kind of transportation system. Perfect balance of the line means to unite the element of work to be done in such a manner that at each station the sum of the elemental times just equals the cycle time [2].

An assembly line consists of (work) stations k = 1,...,m usually arranged along a conveyor belt or a similar mechanical material handling equipment. The workpieces (jobs) are consecutively launched down the line and are moved from station to station. At each station, certain operations are repeatedly performed regarding the cycle time (maximum or average time available for each work cycle).

The cycle time of an assembly line is predetermined by a desired production rate. Such the production rate is set so that the desired amount of end product within a certain time period. In order for an assembly line to maintain a certain production rate, the sum of processing time at each workstation must not exceed the workstation cycle time. If the sum of the processing time within a workstation is less than the cycle time, the idle time is said to be present at that workstation [3].

Many methods have been already examined by researchers, both optimization and heuristics. Branch and bound algorithm for simple assembly line balancing problems has been applied [4], applications of simulated annealing has been implemented in mixed model assembly line balancing [5]. None of them applied trade off between cost of worstation and cost of cycle time considering operator performance.

Optimization assembly line balancing model developed by Elsayed and Boucher aims to minimize the cost of procurement of work stations and the costs associated with the cycle time but does not consider the performance of the operator on each element of work, though the performance the operator is crucial. Optimization model developed by Lesmana and Hartono [6] consider the performance of the operator on each element of work but does not consider the cost of workstation cycle time and cost. This research will accomodate the lackness of each model, we will develop a model for line balancing to minimize the cost of work stations, cycle time cost, operator cost and the cost of idle operators.

Model Development

Developing an optimization model to minimize the amount of work stations and the number of operators so that all costs associated with the number of work stations and the number of operators to a minimum. Previous research (Elsayed and Boucher 1994) have developed a model of assembly line balancing by minimizing the number of stations taking into account the cost of workstation cycle time and cost. Lesmana and Hartono (2003) also developed a model of assembly line balancing by considering the performance of the operator on each element of work. Our model will minimize the number of workstations, cycle time cost as well as operator cost and cost of idle operators.

Minimized $Z = \sum_{s=1}^{S} f_s X_s + \text{c} \;.\; (\max\ T_s) + F_r \;. \sum_{s=1}^{S} X_s \;.\max\ T_s + F_r \;.\; ((\sum_{s=1}^{S} X_s\ \max\ T_s - \sum_{s=1}^{S} T_s\ )/\max T_s)$ (1)

Subject to constrains :

$$\sum_{s=1}^{S} X_{is} = 1 \qquad \forall i = 1 \ldots N \tag{2}$$

$$T_s = \sum_{i=1}^{N}\sum_{k=1}^{K} X_{is} Y_{ks} \left(\frac{W_i}{C_{ki}}\right) \qquad \forall s = 1 \ldots S \tag{3}$$

$$T_s \leq \text{C} \qquad \forall s = 1 \ldots S \tag{4}$$

$$X_{is} \leq \sum_{r=1}^{s} X_{jr} \qquad \forall i = S_i ,\ \forall \text{j} = P_i ,\ \forall \text{s} = 1 \ldots \text{S} \tag{5}$$

$$\sum_{i=1}^{N} X_{is} - \|W_s\| X_s \leq 0, \qquad \forall \text{ s} = 1, 2, \ldots \text{S} \tag{6}$$

$$\sum_{k=1}^{K} Y_{ks} = 1 \qquad \forall s = 1 \ldots S \tag{7}$$

$$\sum_{s=1}^{S} Y_{ks} \leq 1 \qquad \forall k = 1 \ldots K \tag{8}$$

$$X_{is} ,\ Y_{ks} ,\ X_s \in \{0,1\} \tag{9}$$

Objective function (1): minimize total cost of work stations, the total cost of the cycle time, the total cost of the operator including of idle operators. Workstations costs are the costs associated with necessary resources in addition to the work station operator, for example, costs associated with maintenance, depreciation of machinery. Cycle Cost is costs associated with production speed. The total cost of operator associated with the allocation of operators at the work station. This cost is calculated by multiplying the salary of a regular operator with a number of operators at the work station and the actual cycle time. The total cost of idle operators are treated as a lost opportunity. This cost is calculated by multiplying the salary of a regular operator with a total time of idle operators all work stations divided by the actual cycle time. Constrain (2) forces each task to be assigned to workstation (3) calculate the total operating time of each work station based on elements of work and operators who are allocated. Constrain (4) ensure that the total time spent on each work element in the work stations do not exceed the cycle time. Constrain (5) ensure precedence constrain are satisfied. Constrain (6) provides for the minimization of the number of workstation Constrain (7) ensure that each work station operated by one operator only. Constrain (8) ensure that an operator can only handle a maximum of one work station. Constrain (9) zero – one variable that equals 1 if task i is assigned to station s and equals zero otherwise, zero – one variable that equals 1 if operator k is assigned to station s and equals zero otherwise, zero – one variable that equals 1 if station j is assigned and equals zero otherwise.

Numerical Example

There are 9 task. The maximum number of workstation is set to 5 due to layout constrain. The cost of workstation (f_s) => $f_1 = f_2 = f_3 = 15$, $f_4 = f_5 = 20$, The cost of cycle time (c)= 3

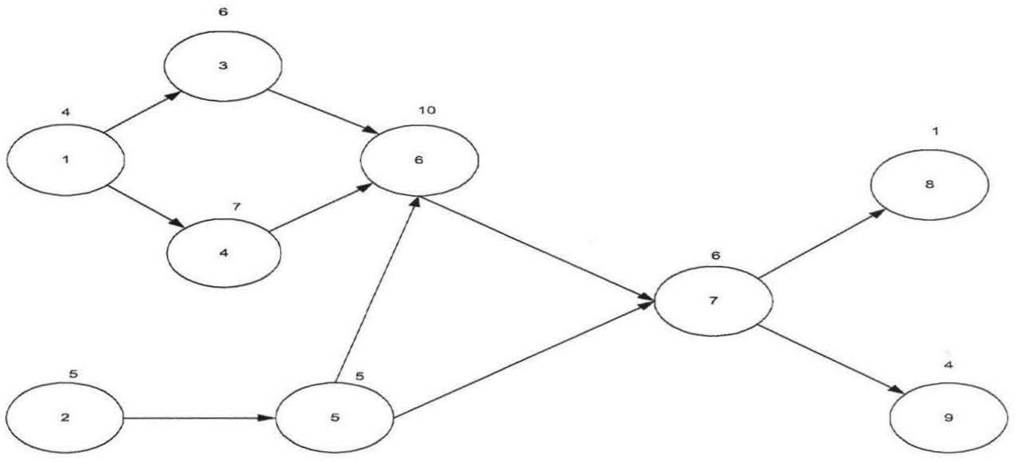

Fig. 1. Precedence diagram for numerical example

Table 1. Task time and presedence requirement

Task	Task time (menit)	Direct Predecessor	Ei	Li	Assigment of Zero-One Variables
1	4	-	1	4	X11, X12, X13, X14
2	5	-	1	4	X21, X22, X23, X24
3	6	1	1	4	X31, X32, X33, X34
4	7	1	1	4	X41, X42, X43, X44
5	5	2	1	4	X51, X52, X53, X54
6	10	3, 4, 5	2	4	X62, X63, X64
7	6	5, 6	2	5	X72, X73, X74, X75
8	1	7	2	5	X82, X83, X84, X85
9	4	7	2	5	X92, X93, X94, X95

Production Rate: 80 unit / week (0.033 unit/minutes),
cycle time = 0.96 / 0.033 unit / minutes = 29.1 minutes
Reguler salary (F_r) = Rp 600.000 / month

= Rp 150.000 / week
= Rp 62.5 / minutes

Cost Of the workstation (f_s) = Rp 125.000 / station

Price of the product = Rp 2.500.000 / unit
Profit =20 % Price of the product = Rp 500.000 / unit
Cycle time cost(c)
= Production rate * Profit
= 0.033 unit/ minutes * Rp 500.000 / unit
= Rp 16.500 / minutes

Table 2. Perfomance rating operator for each task

Operator	*Performance rating* operator for each task (%)								
	1	2	3	4	5	6	7	8	9
1	115	113	117	115	116	118	115	117	112
2	117	119	119	119	112	118	111	120	118
3	113	110	119	120	120	114	113	114	115
4	114	116	120	111	115	120	110	110	111
5	111	117	117	111	111	120	115	113	120

Actual time is obtained by = $\frac{W_i}{C_{ki}}$

where:
W_i = standart time for task i
C_{ki} = *performance rating* operator at each task

Table 3. Result of the Model

Cost Of the Workstation (Rp/stasiun)	Cycle Cost (Rp / menit)	Reguler Cost (Rp /menit)	Number Of Workstation	Cycle Time (menit)	Operator Idle Time (menit)	Total Cost (Rp)
125000	16500	62.5	2	22.26	3.13	620081.3

Due to the number of workstation output were two station, work elements assigned to workstation 1 were number 1,2,3 and 4 and work elements assigned to workstation 2 were number 5,6,7,8 and 9.

Computational Experiment and Analysis

Cost Of the Workstation (Rp / stasiun)	Cycle Cost (Rp /menit)	Reguler Cost (Rp / menit)	Performance Rating	Number Of Workstation	Cycle Time (menit)	Operator Idle Time (menit)	Total Cost(Rp)
10000	25000	62.5	110-120	5	9.43	5.37	288732.5
60000	25000	62.5	110-120	5	9.43	5.37	538732.5
80000	25000	62.5	110-120	4	12.08	6.07	625051.4
100000	25000	62.5	110-120	4	12.08	6.07	705051.4
125000	25000	62.5	110-120	3	16.99	9.28	802970
126000	25000	62.5	110-120	3	16.99	9.28	805970
140000	25000	62.5	110-120	2	22.26	3.13	839291.3
150000	25000	62.5	110-120	2	22.26	3.13	859291.3
125000	16500	62.5	110-120	2	22.26	3.13	620081.3
125000	22000	62.5	110-120	2	22.26	3.13	742511.3
125000	24000	62.5	110-120	3	16.99	9.28	785980
125000	25000	62.5	110-120	3	16.99	9.28	802970
125000	30000	62.5	110-120	4	12.08	6.07	865451.4
125000	35000	62.5	110-120	4	12.08	6.07	925851.4
125000	50000	62.5	110-120	5	9.43	5.37	1099482
125000	60000	62.5	110-120	5	9.43	5.37	1193782
125000	25000	62.5	80-90	4	16.57	8.33	918424
125000	25000	62.5	90-100	4	14.74	7.225	872216
125000	25000	62.5	100-110	4	13.27	7.22	835102
125000	25000	62.5	110-120	3	16.99	9.28	802970

Sensitivity Analysis

Sensitivity analysis conducted to determine how sensitive a model that has been developed to the total cost. It is concluded that cost of workstation increase linearly with total cost because the cost of a workstation is as a part of the total cost. Cycle cost has the same impact. The increasing of performance rating operators gives significant decreasing of total cost. It is because as the increasing the productivity of the operators gives positive improvement of work processing time. This resulted in a lower total cost. It is also examined that the greater the cost of workstation the less the amount of workstation because the trade off function of cycle time. In contrary, the increasing of cycle cost will reduce the number of workstations. This is demonstrate that the model works well.

Summary

A new development model for line balancing by considering the performance rating of operator as well as to minimize cycle time cost and cost of workstations to minimize the total cost has been proposed in this paper. The result of a new model development had been verified as follows:

1. Every work elements will assign at only workstation at time.
2. Presedence constrain restriction was filled.
3. Cycle time was filled.

The result shown that all constraint had fullfilled to minimize total cost. Therefore, the model could work well.

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Nomenclature

i,j : Task Index
s : Workstation Index
k : Operator Index
f_s : Cost of Workstation (Rp).
X_s : Workstation (s), s = 1...S.
c : Cycle Cost (Rp / minutes).
C : Cycle Time
F_r : Regular Operator Salary (Rp / minutes)
N : task
W_i : Standard time task i
C_{ki} : Performance rating operator k for handling task i
X_{is} : zero – one variable that equals 1 if task i is assigned to station s and equals zero otherwise.
Xj : zero – one variable that equals 1 if station j is assigned and equals zero otherwise.
W_s : subset of all tasks that could be assigned to station j by virtue of task precedence constraints
E_i : Earliest workstation that task i can be assigned to, given precedence requirement
L_i : Latest workstation that task i can be assigned to, given precedence requirement
Y_{ks} : zero – one variable that equals 1 if operator k is assigned to station s and equals zero otherwise.
T_s : task time in workstation s