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Mixed-Model Assembly Line Balancing in The Process of Assembling Trimming Area to Minimize Workstation Using RPW-MVM Method

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Abstract. The development of an industry that continues to move forward coupled with global competition and openness demands that the company continues to evolve and always make improvements in improving the performance of its production process. XYZ Corp is an automotive company based in Germany that produces premium cars, the car assembly process groove at XYZ Corp is a trimming line, mechanical line and finishing line, XYZ Corp produces A-model, B-model and C-model cars. At this time XYZ Corp not achieving the production target due to the car assembly cycle time on the trimming Line 1 area exceeds the specified takt time. Assembly line balancing is required in the trimming area using Mixed-Model Assembly Line Balancing Problem (MALBP) approach to minimize the number of workstation, in the Trimming area assembly line balancing study using the Ranked Positional Weighted with Moving Target (RPW-MVM) method. Alocation constraint should be added due to machine restrictions that cannot be moved. After assembly line balancing, there was a decrease in the number of workstations to 14 workstations with a line efficiency of 86% and balancing efficiency of 97%.

1 Introduction

The development of the industrial that continues to move forward coupled with competition and global openness to meet consumer demand makes companies, especially automotive companies continue to grow and always make improvements. The development of the sales market is very competitive and oriented to customer satisfaction. For example, in the automotive industry, products are made based on several different models and features that are oriented to the customers wants. In an effort to fulfill the demand by building and maintaining assembly lines, the company made a single assembly line for several mixed models. In a situation like this, the problem of the balance of the assembly line will arise because of the demands for different models and features that vary with each product produced (Haq, Jayaprakash, & Rengarajan, 2006).

XYZ Corp is a German automotive company that produces premium cars with high performance. Cars manufactured by XYZ Corp has several types of car products such as model A, model B, and model C. The flow of the car assembly process at XYZ Corp is a

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trimming line and a mechanical line. While the engine, door, tire, and dashboard sub-assembly process is an assembly sub-process on the assembly line in the production department, according to Kumar and Mahto (2013) the assembly line model at XYZ Corp has the characteristics of a mixed-model assembly line because the company produces several types of products on 1 track and there is no setup time for changes in the types of products assembled.

The company can only meet the production target of 90%, the processing time for each work station in trimming is different, Figure 1 is a graphical representation of the processing time in the trimming area. Based on the graph data in Figure 1, it can be seen that at some work stations in the trimming area there is a processing time that exceeds the specified takt time, resulting in an unbalanced trimming assembly line which results in some work station bottlenecks and idle time so that the production target is not reached. Therefore it is necessary to balance the workload in the assembly area. This study aims to design a proposed assembly line with an optimal number of work stations with better line efficiency and balancing performance index.

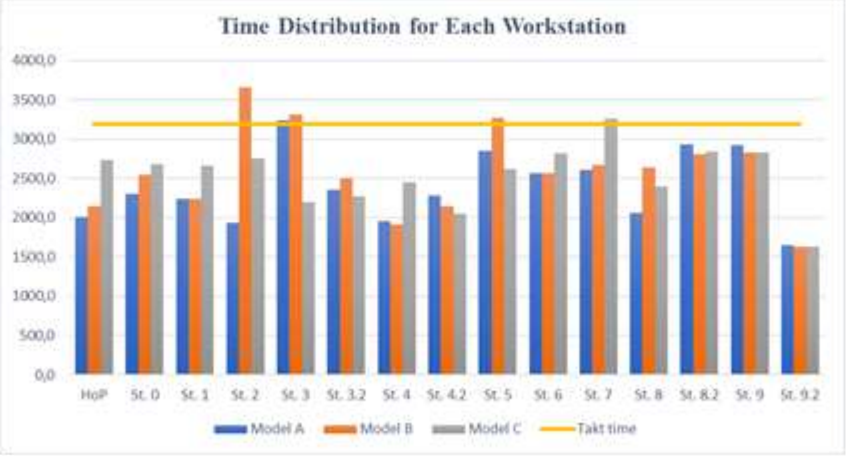

Fig. 1. Time Distribution for Each Workstation

This study focuses on the imbalance of assembly lines. The problem of the imbalance of the assembly line is due to the uneven allocation of workload and the time at several stations that exceed takt time as found in Figure 1. In this study, the balancing of assembly lines is a mixed-model, where assembly lines can produce different models, with adaptability to demand with high levels of efficiency (Reginato et al., 2016). The main purpose of balancing assembly lines according to Eryuk et al (2008) is to minimize the number of work stations with predetermined cycle times or minimize cycle times with the number of work stations that have been determined.

Research "The Design of PC300 Type Hydraulic Excavator Assembly Line System with Genetic Algorithm Method" conducted by Andri Amir (2008) found an increase in productivity from 12 units/day to 13 units/day. Research conducted by Eryuk et al. (2008) regarding "Assembly Line Balancing in a Clothing Company", found that balancing assembly lines using the Ranked Positional Weight (RPW) method resulted in a more optimal number of work stations and line efficiency compared to line balancing using the method Probabilistic Balancing Line. Research conducted by Amen (2001) regarding the solution of assembly-line problems using the heuristic method, found that the heuristic ranked positional weight method has stable results when faced with problems in the real world. Balancing mixed-model assembly lines conducted by Reginato et al. (2016) examines and balances workloads with 7 product models using ranked positional weight with moving target (RPW-MVM) method, the results obtained after workload balancing is increased capacity, line efficiency and balancing efficiency.

Balancing mixed-model assembly lines conducted by Reginato et al. (2016) examines and balances workloads with 7 product models using ranked positional weight with moving target (RPW-MVM) method, the results obtained after workload balancing is incrThe development carried out by Reginato et al. (2016) developed the RPW method in solving problems in the assembly line development, solving assembly line problems using the RPW method which is purely regulated with predetermined cycle times, so that accumulated imbalances can produce assembly line performance. less well, in the RPW-MVM method, there is a limitation of moving target value (MVM) which is used as a reference in balancing and allocating work elements at work stations so that the assembly line is maintained more smoothly and provides a better performance value. eased capacity, line efficiency and balancing efficiency.

This study aims to determine the optimal number of work stations so that it can increase the value of line efficiency and balancing efficiency in the trimming area.

2 Research Method

2.1 Assembly Line Balancing

Assembly line balancing Is a task allocation procedure, where tasks are distributed equally for each assembly work station so that the workload of operators at each work station is balanced (RAJA, 2015). Balance assembly lines are used generally to improve the assembly process for serial work stations. Assembly line balancing is a technique that is often used by industries that want to implement lean manufacturing systems (Kumar and Mahto, 2013). Measures of efficiency (operational performance) of assembly lines can be measured based on (Damayanti and Toha, 2012):

1. Total work stations, each work station will require operating costs, called operational costs.
2. Idle time is a time that is avoided in the context of the efficiency of the assembly line and will result in idle time costs.
3. Waiting time, waiting time in the process is calculated as waiting time cost.

The purpose of balancing assembly lines according to Scholl (1995) is, as follows:

a. Reducing the number of work stations (m) with a predetermined cycle time.
b. Reduce cycle time with the number of work stations that have been determined.
c. Improve line efficiency.
d. Look for a feasible solution with specified cycle time and number of work stations.

2.2 Ranked Positional Weight with Moving Target (RPW-MVM)

Solving line balancing problems on assembly lines using the pure RPW method is set with a predetermined cycle time, so that in allocating work elements to the workstation based on a fixed cycle time, this will result in allocating work elements at each workstation having accumulated imbalances which usually produces poor assembly line performance, to anticipate accumulated imbalances with fixed target limits / fixed cycle times the allocation of work elements must be allocated anywhere and anytime so that line balancing methods are developed on assembly lines based on weighting with moving targets or Moving-Target (MVM). Moving-Target (MVM) calculations on assembly lines are carried out at each work station and balancing assembly lines based on the number of work stations that are then Moving-Target (MVM) values are used as a reference for balancing the allocation of work elements at work stations. Moving-Target (MVM) calculations in the assembly line balancing process will make it easier to configure work stations by allocating work elements in a balanced manner to a predetermined work station (Reginato et al, 2016).

2.3 Performance Indicator

The balancing analysis of assembly lines generated from the RPW-MVM method used is as follows:

1. Line Efficiency (LE)
   Line Efficiency (LE) is an indicator to measure the use of assembly lines that will have an impact on aspects of economic evaluation.

$$LE = \frac{\sum_{i=1}^{k} \mathrm{ST}_i}{K.CT} \,.100\% \quad (1)$$

LE : line efficiency
ST_i : time of the i workstation
K : number of work stations
CT : cycle time

2. Balancing Efficiency
   Balancing efficiency is an indicator that measures the quality of the allocation of work elements to workstations which has an impact on increasing production levels.

$$BE = (1 - \frac{\sum_{j=1}^{W} |\,\overline{Sj} - Sav|}{W\ x\ Sav})\ x\ 100 \quad (2)$$

Sj^{-} : Total station time weighted average
W : Number of workstations
Sav : Average station time

2.4 Alocation Constraint

In the assembly process in the trimming area there are several allocation constraint, this limitation is due to machine restrictions that cannot be moved, some work processes or elements that have allocation constraint including:

a. Work elements C22, C21, C20, C19, C18, C17, C14, C11, C12, C16, C15, C13, C23, C10, C2, C8, C7, C6, C1 must be done at station 3.
b. K2 and K12 work elements must be worked on the same station.
c. Work element A2 must be worked on station 1

3 RPW-MVM Model

3.1 Assembly Line Model

The following model assembly lines at PT. XYZ has the characteristics of mixed-models (Raja, 2015), namely assembly lines making products with several variants, where the operation of work for similar product variants for different variants.
The measured performance indicators are:

a. Number of work stations
b. Line efficiency

3.2 Balance of the Existing Assembly Line

The following is the existing performance index information:

1. The number of existing assembly work stations is 15 work stations.

2. The assembly line working time is 25500 seconds/day, cycle time is 3662 seconds/unit, so the capacity is 7 units/day.
3. The assembly line efficiency is 81% and balancing efficiency is 90%.

3.3 Calculation procedure using RPW-MVM

The following are the calculation procedure steps using the RPW-MVM method to balance workload:

1. The first step is to make a combined precedence diagram for all work elements in each model that is worked on the existing work station, for details can be seen on Figure. 3.
2. Next, calculate the proportion of demand. In balancing assembly lines with many models, each model has a different processing time. The average processing time of each model needs to be defined by determining the proportion of demand.

$$pdm = dm/D \tag{3}$$

Where, dm is product demand in period p, where model m = 1, ... M; and D is the total demand for all models produced. The proportion of demand for each model, the proportion of demand for model A models is 43.5%, model B is 27.4% and model C is 29.1%.

3. Calculate cycle time (TC) / takt time based on total production demand. Takt time is 3187.5 seconds/unit, the allocation of work elements must be under takt time.

$$Tc = \frac{waktu\ tersedia\ pada\ periode\ p}{total\ permintaan\ pada\ periode\ p} \tag{4}$$

4. Calculate the average process time weight ($\bar{tk}$) and Average Station Time Total ($\bar{Sj}$) to allocate work elements to RPW-MVM because this method takes into account all models of a mix-model assembly line.

$$\bar{tk} = \sum_{m=1}^{N} pd_m tk_m \tag{5}$$

$$\bar{Sj} = \sum_{k \in j} \bar{tk} \tag{6}$$

5. Perform RPW calculations for each work element by summing the tk of the preceding process based on the combined precedence diagram.
6. Sort according to the weighting of RPW.
7. Calculate the minimum number of work stations (MinW).

$$CTT_m = \sum_{k=1}^{N} tk_m \tag{7}$$

$$MinW = \frac{CTT_m}{Tc}, \ m = 1,..., M \tag{8}$$

8. Determine the number of work stations j=w.
9. Calculate the moving target number (MVM) for each work station (MVMj,m=1,....,M).

$$CTA_{j,m} = CTT_{j+1,,m} + S_{j,m} \tag{9}$$

$$MVM_{j,m} = \frac{CTT_m - CTA_{j+1,m}}{MinW - (Min\ W - j)} \tag{10}$$

10. Allocating work elements for each model based on RPW weighting values by taking into account the combined precedence diagram and the average weight of the work station ($\bar{Sj}$), allocation of work elements for each work station for all models does not exceed cycle time / takt time (SJ,m = 1, ... , M ≤ Tc
11. Repeat the allocation of work elements until the work elements for each model cannot be moved back.
12. Determine (j = j-1) and do reconsideration MVM j,m=1,…,M.
13. The next step is to validate the level of inequality, that is if ((major MVM j, m = 1, ..., M) ≤ Tc) then do the next step, if ((major MVM j, m = 1, ..., M) ≥ Tc) then repeat step 8 by calculating (MinW = MinW + 1) and repeating the allocation of work elements and then repeating calculations from steps 10 to 13 until all elements of the work are distributed.

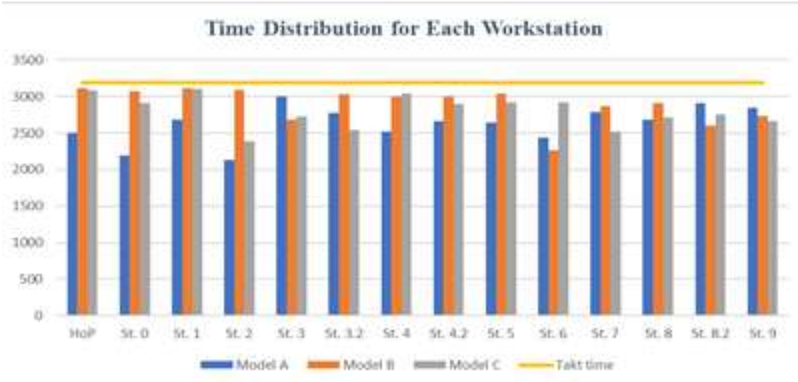

Fig. 2. Time Distribution for Each Workstation after Balancing

4 Conclusions

Based on the results of the calculation and reallocation of work elements for each work station in the trimming area, the optimal number of work stations is found in 14 work stations, with the proposed performance assembly line performance better than the performance index of the existing assembly line. A comparison of proposed and existing performance indexes can be seen in Table 1. After reallocation for each work element, the graph of time distribution for each work station can be seen in Figure 2.

Table 1. Performance Index Comparison

		Current Balancing	New Balancing RPW- MVM
Variable	Time Available in the period (sec)	25500	25500
	Demand (parts/day)	8	8
	Cycle time (sec)	3187,5	3187,5
	Tg (min)	3662	3119
Indicator	Amount of AL workstations	15	14
	Line Efficiency	70%	88%
	Balancing efficiency (BE)	90%	97%

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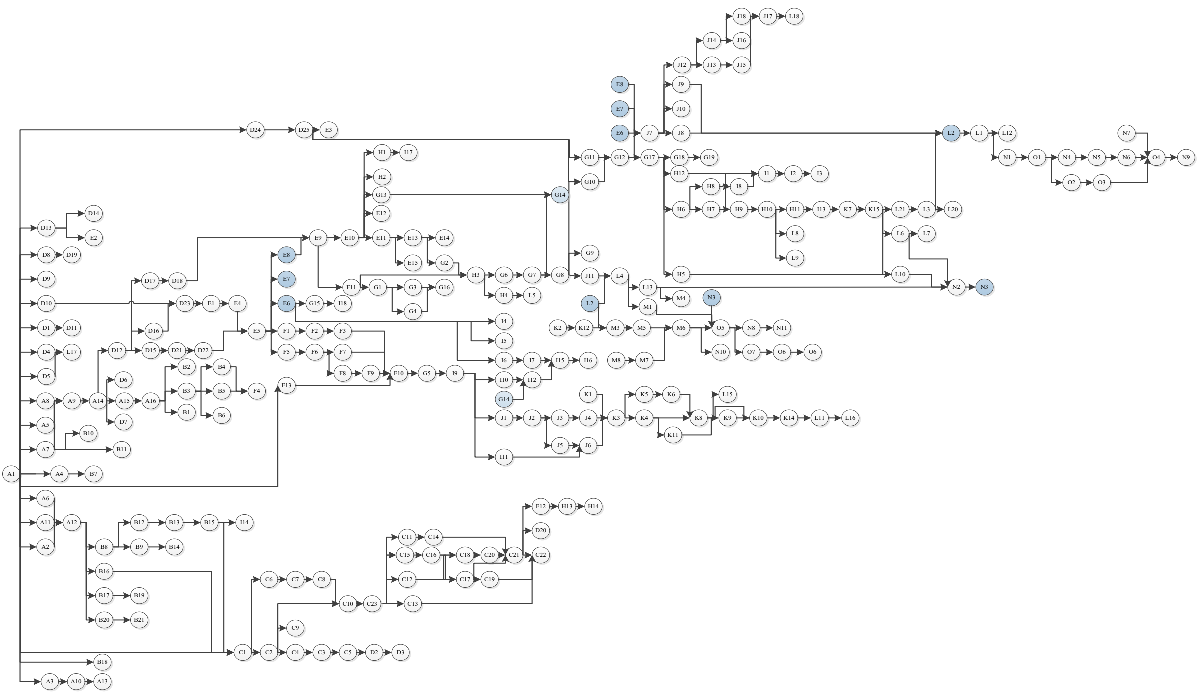

Figure 3. Precedence Diagram

Table 2. Work Element

No	Predesesor	Model			Tk	RPW
		A	B	C		
A1		35	35	35	35	35
A2	A1	350	360	762	473	508
A3	A1		80		22	57
A4	A1	30	40		24	59
A5	A1	33	60	80	54	89
A6	A1	72	55	60	64	99
A7	A1	105	105	95	102	137
A8	A1	58	58	80	64	99
A9	A8, A5, A7	134	140	140	137	393
A10	A1, A3	458	458	458	458	515
A11	A1			80	23	58
A12	A6, A11, A2	125	145	262	170	765
A13	A10	45	45	45	45	560
A14	A9	244	244	244	244	637
A15	A14	280	280	280	280	917
A16	A15	43	43	43	43	960
B1	A16	42		42	30	990
B2	A16	40	40	40	40	1000
B3	A16	90	50	80	76	1036
B4	B3	90			39	1075
B5	B3	93	93	100	95	1131
B6	B3	57	48	80	61	1097
B7	A4	135	120	110	124	183
B8	A12	120	120	160	132	897
B9	B8	75	75	170	103	999
B10	A7	155		110	99	237
B11	A7	300	370	340	331	468
B12	B8	120	120	95	113	1009
B13	B12	480	480	550	500	1510

No	Predesesor	Model			Tk	RPW
		A	B	C		
C13	C23	10	10	10	10	2590
C14	C11	17	17	17	17	2981
C15	C23	33	33	33	33	2613
C16	C15	120	120	120	120	2733
C17	C12, C16	70	70	80	73	2986
C18	C12, C16	135	135	160	142	3055
C19	C17	120	120	120	120	3106
C20	C18	150	140	60	121	3176
C21	C14, C20, C17	360	360	320	348	3999
C22	C21, C13, C19	40	40	40	40	4169
C23	C10			388	113	2580
D1	A1	96	131	96	106	141
D2	C5	60	95	80	75	2603
D3	D2	24	65	30	37	2640
D4	A1	34	69	34	44	79
D5	A9	40	85	50	55	448
D6	A14	122	157	166	144	781
D7	A14	140	175	140	150	787
D8	A1	50	85	80	68	103
D9	A1	75	110	75	85	120
D10	A1	28	63	28	38	73
D11	D1	24	59	24	34	174
D12	A14	80	115	80	90	727
D13	A1	326	361	326	336	371
D14	D13	50	85	70	65	436
D15	D12		115		32	758
D16	D12		253	120	104	831
D17	D12		169	134	85	812
D18	D17	150	245	280	214	1026

No	Predesesor	Model			Tk	RPW
		A	B	C		
B14	B9	60	60		43	1042
B15	B13	445	445	505	462	1972
B16	A12		350		96	861
B17	A12		110		30	795
B18	A1		15		4	39
B19	B17		50		14	809
B20	A12			100	29	794
B21	B20			152	44	838
C1	B16, B15	120	120		85	2068
C2	C1	237	237	237	237	2305
C3	C4	207	207	207	207	2517
C4	C2		18		5	2310
C5	C3	15	15		11	2528
C6	C1	100	110		74	2142
C7	C6	50	50		35	2177
C8	C7	60	60		43	2220
C9	C2	24			10	2316
C10	C2, C8	40	40	40	40	2467
C11	C23	275	275	650	384	2964
C12	C23	180	180	180	180	2760

No	Predesesor	Model			Tk	RPW
		A	B	C		
D19	D8	160		100	99	202
D20	C21	190	245	230	217	4216
D21	D15	170	205	200	188	946
D22	D21	146	181	160	160	1106
D23	D16, D10		85	50	38	906
D24	A1	70	105		59	94
D25	D24		535	240	216	311
E1	D23	70	55	70	66	972
E2	D13	115	100	115	111	481
E3	D25	145	130		99	409
E4	E1	30	25	20	26	998
E5	D22, E3, E4	705	705	600	674	2052
E6	E5	180	165	50	138	2190
E7	E5	130	115		88	2140
E8	E5	240	265	200	235	2287
E9	D18, E5, D9	520	505	450	496	3166
E10	E9	360	370	250	331	3497
E11	E10	265	265		188	3685
E12	E10, E2	90	75	90	86	4029
E13	E11, E12	350	335	300	331	4549