A Comparative Study Of Largest Candidate Rule And Ranked Positional Weights Algorithms For Line Balancing Problem

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Abstract

The manufacturing companies are competing among themselves to be the leading manufacturer in the share market. With the rapid increasing competition in the market, the companies need to improve their operation by producing high-quality products, operated at the lowest possible cost. Thus, to achieve this target, the bottleneck problem which affects the idle time and efficiency in the assembly line needs to be investigated. Besides, it also affects the production rate of the assembly line and can have a huge impact on the increase in operational costs. Since there are various line balancing algorithms available as the solution for the bottleneck problem, it is crucial to determine which line balancing algorithm works the best for the associated assembly line. Therefore, this study aims to analyze and compare the two most frequently used line balancing algorithms, which are the Largest Candidate Rule (LCR) and Ranked Positional Weights (RPW) algorithm. The studied applied to three different industries, which are electronic, food and automotive industries. The analysis and comparison are achieved through findings from Microsoft Excel calculation and simulation in Delmia Quest. The study indicates the best line balancing algorithm for the line balancing problem by these two parameters which are the line balance efficiency, Eb and the balance delay, d. According to the findings of the study, the best line balancing algorithm is dependable on the case study to be solved.

Keywords: Comparative study, Line balancing, Single Model, RPW, Largest Candidate Rule (LCR), Ranked Positional Weights (RPW), Microsoft Excel, Delmia Quest.

1. INTRODUCTION

An assembly line is an industrial arrangement that contains a sequence of workstations where assembly tasks are performed by the workers continuously. The flow of an assembly line is designed by analyzing the steps involved in the manufacturing of each product component and the final product. The design assembly line must be intended to achieve sufficient production rate to meet the demand for the product. If an assembly line is imbalanced, it brings a bottleneck issue in the assembly line. A bottleneck situation is a condition where congestion of production system occurs. The situation occurs when the workloads arrive too quickly for the workstation to manage. The line pacing of the assembly line can become too fast, or too slow, affecting work build up between the workstations. Besides, it can increase operational costs to an organization. Thus, it is crucial to apply a line balancing algorithm to achieve a balanced line.

However, since there are various algorithms of line balancing available, it is essential to compare them in order to achieve the best solution for line balancing problems. Each line balancing problems may have different line balancing algorithms as the solution. Therefore, there is a critical need to compare and determine which algorithms work best for the line balancing problem.

2. LITERATURE REVIEW

LCR algorithm has been applied in several research such as [1], [2], [3] and [4]. This algorithm is applied on multiple categories of industry in order to solve line balancing problem in assembly line. RPW algorithm has been utilized in several research such as [2] and [5] in developing the solutions for line balancing problem in multiple industries.

Delmia Quest provides a collaborative environment for industrial and manufacturing engineers to build and deliver the best manufacturing flow procedures throughout the production design process. This software also offers both visual and numerical analysis as an outcome mention by [6]. In Delmia Quest, the user can create and design facility layout, process flow, staff schedules, machine arrangement and ergonomics constraint in their virtual factories [7].

A. *Case Study1 (Electronic Industry)*

We applied three case studies with different types of industries. All case studies are applied with both *LCR* and *RPW* algorithms in Microsoft Excel and Delmia Quest.

Case Study Table 1 below shows the list of work elements in the electronic industry. This assembly line consists of 12 work elements to produce the end product. Each work elements have their own predecessor. The input data of the electronic industry assembly line is compiled, as shown in Table II-2 below.

Table 1: Work Elements of an assembly line in an Electronic Industry

Work Elemer	Work Element Description	Work Content Time, Tek (min	Preceded by
1	Place frame in workholder & clamp	0.2	-
2	Assemble plug, grommet to power cord	0.4	-
3	Assemble brackets to frame	0.7	1
4	Wire power cord to motor	0.1	1,2
5	Wire power cord to switch	0.3	2
6	Assemble mechanism plate to bracket	0.11	3
7	Assemble blade to bracket	0.32	3
8	Assemble motor to brackets	0.6	3,4
9	Align blade & attach to motor	0.27	6,7,8
10	Assemble switch to motor bracket	0.38	5,8
11	Attach cover, inspects & test	0.5	9,10
12	Place in tote pan for packing	0.12	11

B. *Case Study 2 (Food Industry)*

Table 2 below displays the list of work elements in the food industry. This food production line produces tofu. The tofu production line consists of 15 work elements, and each work elements have its assigned predecessor to produce the end product. The input data of the food industry assembly line is compiled, as shown in Table 2 below.

Table 2: Work Elements of an assembly line in a Food Industry

Work Element	Work Element Description	Work Content Time, Tek (min)	Preceded by
1	Feeding soybean	0.5	-
2	Soybean delivery	0.2	1
3	Soybean washing & soaking	0.5	2
4	Soybean grinding separating	0.4	3
5	Soymilk cooking	0.5	4
6	Coagulating, curd breaking & filling to tofu mold	0.4	5
7	Stacking tofu molde	0.3	6
8	Tofu pressing	0.2	7
9	Turning tofu mold	0.3	8
10	Tofu cutting	0.1	9
11	Tofu cooling	0.4	10
12	Sealing	0.3	11
13	Strilizing & cooling	0.5	12
14	Drying	0.6	13
15	Packaging	0.4	14

C. Case Study 3 (Automotive Industry)

Table 3 below illustrates the list of work elements in the automotive industry. The automotive assembly line manufactures automobile lighting production. This assembly line contains 14 work elements and has its own designed predecessor to deliver the end product. The input data of the food industry assembly line is compiled, as shown in Table 3 below.

Table 3: Work Elements of an assembly line in Automotive Industry

Work Element	Work Element Description	Work Content Time, Tek (min)	Preceded by
1	Reflector inspection	0.17	-
2	Lens inspection	0.17	1
3	Hot melt robot	0.28	2
4	Lens pressing	0.28	3
5	Leak testing	0.30	4
6	Bulb holder spring fitment	0.23	5
7	Bulb fitment	0.35	-
8	Dust cap vent tube fitment	0.23	7
9	Full assembly dust cap fitment	0.32	8, 6
10	Parking wire fitment	0.25	9
11	U shape vent tube fitment	0.20	10
12	Photometric light testing	0.45	10
13	Final inspection	0.27	11, 12
14	Packing	0.22	13

3. METHODOLOGY

The purpose of the equations in the line balancing analysis is to measure and indicate the effectiveness of a given line balancing solution on the assembly line[2]. The calculation helps in analyzing and choosing the best line balancing algorithm for each industry in this study. Two software are used in this study, which is Microsoft Excel and Delmia Quest. The aim of Microsoft Excel in this study is for calculation and analysis purposes on all three case studies. On the other hand, the goal of Delmia Quest in this study is for creating a simulation of an assembly line of all three different industry categories also to validate the findings in Microsoft Excel. Two types of simulations are formed on each case study, which is a virtual assembly line with LCR and RPW algorithms. In addition, the results from each simulation are counted as data analysis for comparative between two-line balancing algorithms. The study divided into three stages with the aim of achieving three objectives of the study.

4. RESULT & DISCUSSION

After both LCR and RPW applied to all three case studies, a set of data is gathered from findings in Microsoft Excel and Delmia Quest. The following is the result of each case study.

A. Result & Discussion of Case Study 1

After applying both line balancing algorithms, the study finds that the RPW algorithm is the best line balancing algorithm for the first case study. RPW algorithm provides a better solution in balancing assembly line in terms of the increased in assembly line performance, reducing idle time, and lesser human workers are needed to operate this assembly line.

As shown in Table 4 the initial line balancing efficiency, Eb for this electronic industry assembly line, is at 48%. Meanwhile, the initial balance delay, d is at 52%. When the LCR algorithm is applied to this assembly line, Eb is improving by 32% and the balance delay is reduced to 20%. The line balancing efficiency is at the best when applying RPW algorithm which Eb is at 87% and d is only at 13%.

Table 4: Calculated Findings

	Groover (1980)		This Research (2020)	
	LCR	*RPW*	*LCR*	*RPW*
Line balancing efficiency, E_b	80%	87%	80%	87%
Balance delay, *d*	20%	13%	20%	13%
Number of workers, *w*	5	5	5	5

In addition, the number of workers is decreasing due to the reducing number of workstations in LCR and RPW algorithms. The total number of workers initially are eight workers. By applying both algorithms, the number of workers decreased to only five workers needed to operate this assembly line.

On the side note, the findings of the analysis of this assembly line with both algorithms support the findings by [2]. The same assembly line with the same line balancing algorithms obtains similar findings in two studies. To validate the findings in Microsoft Excel, the simulations of assembly line with LCR and RPW algorithm are created in Delmia Quest as displayed in Figure 3 and 4. Both simulations ran for 3600 seconds to obtain the performance of both assembly lines per hour.

Based on the Table 5 below, it displays that RPW algorithm has a better production rate and lower idle time for this assembly line. It proves that the RPW algorithm provides an enhanced solution for this electronic industry assembly line due to improvement in production rate, idle time, the number of workers and performance of line balancing efficiency and balance delay.

Table 5: Summary of Findings from Simulations

	Production Rate (unit/hour)	Idle time (hour)
LCR Algorithm	56	1.12
RPW Algorithm	61	0.748

B. Result & Discussion of Case Study 2

After applying both line balancing algorithms, the study discovers that LCR and RPW algorithms provide the same results for this food industry assembly line. All the findings in both algorithms are identical, including the amount of idle time, the number of workers, line balancing efficiency and balance delay. However, the performance of the assembly line after applying line balancing algorithms is improved compared to the initial assembly line.

Table 6 shows the initial line balancing efficiency, Eb for this food industry assembly line is at 62% and the initial balance delay is at 38%. Both initial values of performance are at moderately bad category. As LCR and RPW are applied on this assembly line, the amount of Eb is improving by 18% which makes the current Eb is at 80% for both algorithms. In addition, the balance delay for both algorithms are decreased to 20%. Furthermore, as the number of workstations is reducing, the total of workers needed in the assembly line is also decreasing. Based on these findings and analysis, it shows that both LCR and RPW algorithms bring positive impacts on this assembly line. To validate the findings in Microsoft Excel, the two simulations of assembly line with LCR and RPW algorithm is created in Delmia Quest as shown in Figure 6 and 7. The simulations ran for 3600 seconds to obtain the performance of assembly lines per hour.

The findings of both simulations support the results and analysis in Microsoft Excel. Table IV-3 below recaps the findings from both simulations for LCR and RPW algorithms. It proves that both LCR and RPW algorithm have the identical results and provide the same solution for this food industry assembly line in term of improvement in production rate, idle time, number of workers and performance of line balancing efficiency and balance delay.

Table 6: Summary of Findings from Simulations

	Production Rate (unit/hour)	Idle time (hour)
LCR Algorithm	54	0.803
RPW Algorithm	54	0.803

C. Result & Discussion Case Study 3

After applying both line balancing algorithms, the study finds that LCR algorithm is the best line balancing algorithm for the third case study. LCR algorithm offers a greater solution in balancing assembly line in terms of the increased assembly line performance, reducing idle time, and lesser human workers are needed to operate this assembly line. Figure 8 below shows the initial line balancing efficiency, Eb for this automotive industry assembly line is at 59%. Meanwhile, the initial balance delay, d is at 41%. The initial performance of the assembly line is moderately bad. As LCR algorithm is applied to this assembly line, Eb is improving by 27% and the balance delay is reduced to 27%. On the contrary, the line balancing efficiency decreases when applying RPW algorithm compared to LCR algorithm. The line balance efficiency of RPW algorithm is reduced to 74% and d is increased to 26%.

In addition, the number of workers is decreasing due to the reducing number of workstations in LCR and RPW algorithms. The total number of workers initially is ten workers. By applying both algorithms, the number of workers decreased to only seven workers needed for LCR algorithm and 8 workers assigned for RPW algorithm. On the side note, the findings of the analysis of this assembly line with LCR algorithm have slightly different to findings by [3]. Due to several reasons, the same assembly line with same line balancing algorithm obtains different outcomes in two studies. The differences of Eb and d is only 0.5% meanwhile the difference in the number of workers is only one worker.

To verify the findings in Microsoft Excel, the two simulations of the assembly line with LCR and RPW algorithm is created in Delmia Quest. The simulations ran for 3600 seconds to obtain the performance of assembly lines per hour. The findings of both simulations support the findings and analysis in Microsoft Excel. Table 6 below recaps the findings from both simulations for LCR and RPW algorithms. It proves that LCR algorithm has better result compared to RPW algorithm for automotive industry assembly line. LCR algorithm improves performance of assembly line in term of production rate, idle time, number of workers and performance of line balancing efficiency and balance delay.

Table 6: Summary of Findings from Simulations

	Production Rate (unit/hour)	Idle time (hour)
LCR Algorithm	90	1.145
RPW Algorithm	88	2.315

In summary, each case study achieved its own line balancing algorithm for the solution to line balancing issue. Table 7 below summarizes the analysis of all three case studies in Microsoft Excel. It explains that RPW algorithm has the best performance in improving the assembly line in the first case study. For the second case study, both LCR and RPW algorithms have the same results in enhancing the assembly line for the food industry. Moreover, for the third case study, the best line balancing algorithm is RPW algorithm.

Table 7: Summary of Analysis in Microsoft Excel

	Line Efficiency, Eb		Balance Delay, d		Idle Time (min)		Number of workers, w	
	LCR	*RPW*	*LCR*	*RPW*	*LCR*	*RPW*	*LCR*	*RPW*
Case Study 1	80%	87%	20%	13%	0.78	0.32	5	5
Case Study 2	80%	80%	20%	20%	1.10	1.10	7	7
Case Study 3	86%	74%	14%	26%	0.25	0.86	7	8

The findings in Delmia Quest support the analysis in Microsoft Excel for each case study. The validations are made based on the production rate, idle time and the number of workers in the simulations. As a compilation of data in Table 8 below shows that RPW algorithm is the best algorithm for Case Study 1. Moreover, for the second case study, LCR and RPW algorithms provide the same best solutions for the food industry. Meanwhile, LCR algorithm is the best method available for Case Study 3.

Table 8: Summary of Analysis in Delmia Quest

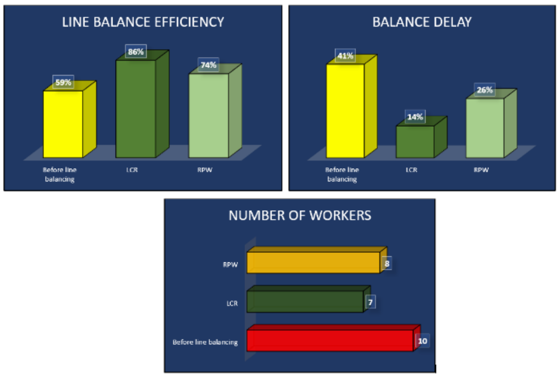
	Production Rate (unit/hour)		Idle Time (hour)		Number of workers, w	
	LCR	*RPW*	*LCR*	*RPW*	*LCR*	*RPW*
Case Study 1	56	61	1.12	0.748	5	5
Case Study 2	54	54	0.803	0.803	7	7
Case Study 3	90	88	1.145	2.315	7	8

Therefore, after implementing two-line balancing algorithms on three different industries, the study discovers that the best line balancing algorithms differs from each other as recaps in Table 9 below. According to Table 9, RPW algorithm provides the best solution for Electronic Industry. Meanwhile, for Food Industry, both LCR and RPW algorithms equally give a better solution compared to initial assembly line. For the third case study, LCR algorithm offers better results compared to RPW algorithm. The performance of a proposed line balancing algorithm depends on the case study to be solved. Some line balancing algorithms work better on a particular problem, while other algorithms work better on other problems.

Table 9: Summary of The Best Line Balancing Algorithm for Case Study

Case Study	Best Line Balancing Algorithm
Case Study 1 (Electronic Industry)	Ranked Positional Weights
Case Study 2 (Food Industry)	Largest Candidate Rule & Ranked Positional Weights
Case Study (Automotive Industry)	Largest Candidate Rule

Table 9: Comparison of Performance of Line Balancing Algorithms



5. CONCLUSION

Based on the findings and analysis in both software in this study, the implementation of line balancing algorithms on all three industry categories are successful. The line balancing analysis proved that applying a line balancing algorithm on the assembly line brings a positive impact in many aspects. The performances of each assembly line are improving in line balancing efficiency, balance delay, idle time and the number of workers needed for the operation of the assembly line.

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