DEVELOPING PROPOSED LAYOUT FOR INCREASING LINE EFFICIENCY ON BODYSHOP

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ABSTRACT

Recently, an imbalance workstation in the assembly line is one of the critical problem that many companies face. Many researches have done to solve this problem with the various designs of assembly line balancing. This research presents the comparison between straight line balancing and u-shaped line balancing. Both straight line balancing and u-shaped line balancing have the same goal; minimizing the workstations. The result of this research shows that u-shaped line balancing gives a better solution than the straight line balancing in term of number of workstation. Straight line balancing is using Rank Positional Weight (RPW) whereas u-shaped line balancing is using Critical Task Method (CTM). Significantly, u-shaped line balancing is more efficient than straight line balancing.

Keywords : assembly line balancing, straight line balancing, u-shaped line balancing, Rank Positional Weight, Critical Task Method

I. INTRODUCTION

Recently the automotive industry is growing rapidly. It leads the bodyshop’s factory be a promising business because the automotive company could not stand itself without the bodyshop’s activities. There are three kinds of bodyshop’s activities; light repair, medium repair, and heavy repair. The standard time for light damage (1-3 panels) is 1 day or more and less than 3 days. For medium damage (4-6 panels) is 3 days or more and less than 5 days and for the heavy damage (≥ 7 panels) is more than 5 days or around 2 weeks. Form the observation, it is found that the actual repair time of light damage is 4.44 working-days (more than 3 working-days) and the repair time of medium damage is 7.02 working-days (more than 5 working-days).

Based on the observation data above, the line efficiency of bodyshop is still low. The line of bodyshop is not balance, it makes many vehicles got stuck when entering the stalls. There are two types of assembly line balancing that matches for the condition of bodyshop; straight line balancing and u-shaped line balancing. Straight line balancing means a balance production line in which stations are arranged consecutively in a line by grouping tasks into stations while moving forward through a precedence diagram by using Rank Positional Weight. On the other hand, u-shaped line balancing is a balance production line is arranged by assigning tasks into stations while moving forward, backward, or simultaneously in both directions through the precedence diagram by using Critical Task Method.

II. LITERATURE STUDY

A. Standard Time (Time Study)

1. Validity Test

There are three kind of test to prove the observation’s data is valid:

a. Normality Test

While confidence interval construction is about unknown population mean μ based upon the calculation of a point estimate and level of confidence, hypothesis testing allows an experimenter to assess the plausibility and credibility of a specific statement (Hayter, 2000). Actually, the state of H_0 and H_A could be explained below.

H_0 : The data is normally distributed

H_A : The data is not normally distributed
If the p-value ≤ α (significance level), the null hypothesis is rejected. The significance level for this research is 5%.

b. Uniformity Test
There are several steps to determine the uniformity of a set of data:
   i. Calculate average observed time ($\bar{x}$) for each operation.

$$\bar{x} = \frac{\sum_{i=1}^{N} xi}{N} \quad (1)$$

   ii. Calculate the standard deviation (s) of each operation.

$$s = \sqrt{\frac{\sum_{i-1}^{N}(xi - \bar{x})^2}{N-1}} \quad (2)$$

   iii. Determine the Upper Control Limit (UCL) and Lower Control Limit (LCL) (Wignjosoebroto, 2000).

$$UCL = \bar{x} + 3s$$
$$LCL = \bar{x} - 3s \quad (3)$$

   iv. Suficiency Test
   The data is sufficient when n (number of data) greater than N' (number of observation needed). The following formula is calculating how many observations must be done to reach 95% confidence level (Sutalaksana, 2006).

$$N' = \left(\frac{40\sqrt{N.\sum xi^2 - (\sum xi)^2}}{\sum xi}\right)^2 \quad (4)$$

2. **Rating Operator Performance (Westinghouse System)**
Niebel (2003) put the detail of westinghouse system as the rating method. This method considers four factors in evaluating the performance of operator; skill, effort, conditions, and consistency. The overall performance factor could be determined by algebraically combining the four values and adding their sum to unity.

3. **Adding Allowance**
Sutalaksana (2006) determines the factors as energy that be taken out, work posture, work motion, eye fatigue, temperature condition, atmosphere condition, and good environment condition. The evaluation is done by calculating the values of the seven factors, personal needs, and delays.

B. Rank Positional Weight (Straight Line Balancing)

There are some steps in Helgeson-Birnie Approach method to design assembly line:

1. Create the precedence matrix to show the relationship among those elements. The following figure is established to show the precedence matrix. The numeral 1 signifies a “must precedes” relationship.
2. Calculate Positional Weight (PW) for every work element (WE).
3. Sort all work elements from the largest PW until the smallest PW. Listing all the positional weight in decreasing order of magnitude.
4. Based on the rank of PW in step 2, develop the task loading into work station. Because of that, there will be some limitations:
   - The relation in Precedence Diagram (+Status zone/ zone constraints)

- Work station time (ST) could not be more than actual cycle time (CTi)

5. Calculate the work station's efficiency and efficiency of assembly line (LE).

C. Critical Task Method (U-Shaped Line Balancing)

Yeh and Kao (2009) in Fathi et all (2011) proposed a new approach based on critical path methods (CPM) in order to solve bidirectional assembly lines, and the time complexity of this method is only O(mn2), meaning that this method can be solved within a polynomial-time. Because of the advantage of less time complexity, in this study the effective heuristic method is presented which is based on combining the proposed approach by Yeh and Kao (2009) and the well-known rank positional weight technique (RPW) introduced by Helgeson and Birnie (1961) to solve U-shape assembly line problems in the area of type-1. There are several steps to do the CTM:

1. Calculating minimum feasible number of workstation S and the minimum feasible cycle time MCT and the adjusted value of CT* = (MCT + CT) / 2.
2. Creating a new workstation, calculating the weight for each task in two stages, one time from the forward direction and another time from the backwards direction and then identifying activities permitted for assigning and creating a candidate list.
3. Assigning activities with high weight on the candidate list; if there are two or more activities with the same weight one of them can be selected to be assigned at random. This order in each stage is continued by finding the new weight for each task using the critical path, because when solving U-shape line the tasks' weight should be updated in the forward direction when the assigned task is from the end of network; otherwise, the tasks' weight in the backward direction should be calculated again, until all the activities are assigned to the workstations.
4. Computing the remaining time for the current station and updating the candidate list based on the new calculated weights and constraints; if the station has enough time for any feasible unassigned task go to step 3, otherwise go to step 5.
5. The assigning process will be repeated until no tasks are left. If there are unassigned tasks, go to step 2.

D. Activity Relationship Chart

Activity Relationship Chart (ARC) can be defined as the maping of activity relation that describe the closeness degree of every facility. Mulyati and Rachmi (2011) set the main goal of ARC is to know the relationship closeness of each group's activity in terms of factory organization. There are six symbols of ARC's closeness degree.

Table 1. Table closeness degree

Code	Closeness Degree
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness OK
X	Undesirable
U	Unimportant

The dimensionless block diagram is the first attempt and the result of the ARC. This layout will be the basis for the master layout and plot plan. The following table is the position requirements of placing the relationship codes.

Table 2. Position in dimensionless block diagram

Code	Position
A	in the top left-hand corner
E	top right corner
I	bottom left corner
O	bottom right corner
U	relationship omitted
X	in the center under the department number

E. Simulation Modelling

A model is a simplified representation of reality, the exact way in whuch an operation is performed is not so important as the way in which the operation impacts the rest of the system (Harrell et al, 2012). There are four basic of model building in Simulation Modelling (Promodel 7): location, entities, arrival, and processing.

1. Bonferroni Approach

In Harrell et al. (2012), the statistical methods for making the comparison of system are called hypotheses tests. One of the methods that could be used is Bonferroni Approach. When there are three to about five alternative system designs to compare with respect to some performance measure, the Bonferroni approach is the method to solve it. Given K alternative system designs to compare, the null hypothesis H0 and alternative hypothesis H1 become :

H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k = \mu$ for K alternative systems

H_1: $\mu_i \neq \mu_{i'}$ for at least one pair $i \neq i'$

where i and i' are between 1 and K and i < i'.

The number of pairwise comparisons for K candidate designs is computed by K(K – 1) / 2.

2. Model Verification and Model Validation

There is a way to do the model verification; using trace and debugging facilities. Comparing with the actual system is one of the techniques that could be used to validate the model. Using the paired-t test for comparing the model with the actual system. In paired-t test, it is necessary for testing the hypotheses;

$$H_0: \mu_1 - \mu_2 = 0$$

$$H_1: \mu_1 - \mu_2 \neq 0$$

Thus, the paired-t confidence interval for an α level of significance is

$$P(\bar{x}_{(1-2)} - hw \leq \mu_{(1-2)} \leq \bar{x}_{(1-2)} + hw) = 1 - \alpha$$

F. Line Efficiency, Smoothness Index, and Balance Delay

There are three parameters in designing the assembly line balancing.

- The efficiency of assembly line (ratio between total workstation time and multification of cycle time and number of workstations).

$$LE = \frac{\sum_{i=0}^{K} STi}{(K)\,(CT)} \; x\ 100\% \qquad (5)$$

LE = efficiency of assembly line
STi = workstation time i
K = number of workstations
CT = cycle time

- The smoothness index (index that shows the relative smoothness of the assembly line).

$$SI = \sqrt{\sum_{i=1}^{K}(STmax - STi)^2} \quad (6)$$

SI = smoothness index
STmax= maximum workstation time
STi = workstation time i

- The balance delay (the rate of delay).

$$BD = \frac{(K)\ (STmax) - \sum_{i=1}^{K} ti \times 100\%}{(K)\ (STmax)} \quad (7)$$

BD = balance delay
K = number of workstation
STmax = maximum workstation time
ti = work element time

III. RESEARCH METHODOLOGY

A. Initial Observation

In this stage, it was observed the current condition in the line by using direct observation and interview. The objective of this step is to understand the actual problem occurred in the line.

B. Data Collection and Calculation

The steps for conducting the data collection and calculation are follows:

1. Determining the work elements.
2. Determining the standard time of each work element/operation using time motion study.
3. Determining the proposed line using Rank Positional Weight method (Straight Line) and using Critical Task Method (U-Shaped)
4. Designing the layout for straight line flow and u-shaped flow from the result of line balancing method from step 3.
5. Conducting the simulation for the proposed line with straight line flow and u-shaped flow. Simulation is conducted using Promodel software. The verification is done by using the software trace in the Promodel and the validation is done using bonferroni approach.

C. Analysis

Compare the current condition and proposed line balancing in line efficiency, smoothness index, and balance delay.

IV. DATA COLLECTION AND ANALYSIS

A. Current Condition

Current work arrangement and yamazumi chart below identifies the two facts about actual time; some workstations violate the takt time (workstation 4, 5, and 7), the process is rough from one workstation to another. The standard time for all work elements are attached as Appendix 1.

Table 3. Actual cycle time of work arrangement

No	Operation	Workstation Time (min)	Number of operator
1	Q1 + Q2 +Q3	4,69	1
2	Q4 + Q5 + Q6 + Q7 + Q8	7,53	1
3	Q9 + Q10 + Q11 + Q12	22,41	1
4	Q13 + Q14 + Q15 + Q16 + Q17 + Q18	64,76	1
5	Q19 + Q20 + Q21 + Q22 + Q23 + Q24 + Q25 + Q26 + Q27 + Q28	60,28	1
6	Q29 + Q30 + Q31 + Q32 + Q33 + Q34	20,84	1
7	Q35 + Q36 + Q37 + Q38 + Q39 + Q40 + Q41 + Q42 + Q43 + Q44 + Q45	55,12	1
8	Q46 + Q47	3,18	1
Total		238,82	8

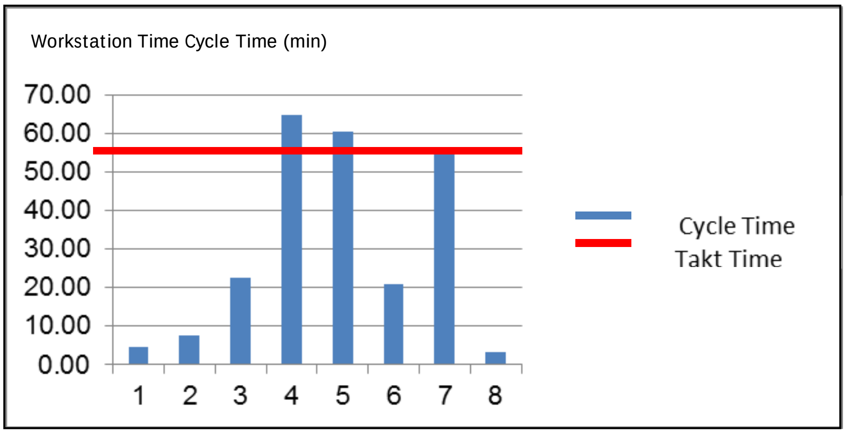


Figure 1. Actual yamazumi chart of bodyshop

The line efficiency of current condition is calculated using formula number 5 and the result is:

$$LE = \frac{238,82}{8 \times 64,76} \, x \; 100\% = 46,1\%$$

The smoothness index of each process is shown below:

Table 4. Smoothness Index of Current Line

Operator	STi	$(STmax-STi)^2$
1	4,69	3608,79
2	7,53	3274,80
3	22,41	1793,21
4	64,76	0,00
5	60,28	20,06
6	20,84	1928,91
7	55,12	92,89
8	3,18	3792,13
Total		14510,79
Smoothness Index		120,46

Due to bottleneck and idle time which occur in the bodyshop line, a delay arises. The value of delay is calculated below.

$$BD = \frac{(8)(64{,}76) - 238{,}82}{(8)(64{,}76)} x\ 100\% = 53{,}9\%$$

B. Proposed Straight Line using Rank Positional Weight

To propose the straight line flow of the line balancing is employed the Rank Positional Weight (RPW) based on the precedence diagram (see Appendix 2). The details calculation of each operation's weight is shown as Appendix 3. The example of calculation the weight of operation Q1 is shown below. Since Q1 precedes all operations except Q22, Q26, Q32, and Q45, the operational weight of Q1 is:

$$\sum \begin{matrix} Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14, Q15, Q16, Q17, \\ Q18, Q19, Q20, Q21, Q23, Q24, Q25, Q27, Q28, Q29, Q30, Q31, Q33, Q34, \\ Q35, Q36, Q37, Q38, Q39, Q40, Q41, Q42, Q43, Q44, Q46, Q47 \end{matrix}$$

=0,92+1,34+2,44+1,50+1,84+2,76+1,09+0,36+2,01+7,74+3,23+9,44+5,19+0,84 +44,38+1,52+11,72+1,12+4,74+2,58+0,63+0,50+1,40+2,63+10,09+34,85+1,92+ 3,87+3,64+4,93+2,65+3,01+6,94+2,41+7,95+3,68+2,04+13,31+1,93+5,60+2,79+ 1,77+1,41

= 226.66

The table below is the work arrangement of straight line balancing based on RPW.

Table 6 Proposed work arrangement of straight line (RPW)

Workstation	Operation	Workstation Time (min)	Number of operator
1	Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8 + Q9 + Q10 + Q11 + Q12 + Q13	39,52	1
2	Q14 + Q15 + Q16	46,74	1
3	Q17 + Q18 + Q19 + Q20 + Q21 + Q22 + Q23 + Q24 + Q25	26,2	1
4	Q26 + Q27 + Q28	46,92	1
5	Q29 + Q30 + Q31 + Q32 + Q33 + Q34 + Q35 + Q36 + Q37 + Q38 + Q39	44,84	1
6	Q40 + Q41 + Q42 + Q43 + Q44 + Q45 + Q46 + Q47	34,32	1
TOTAL		238,54	6

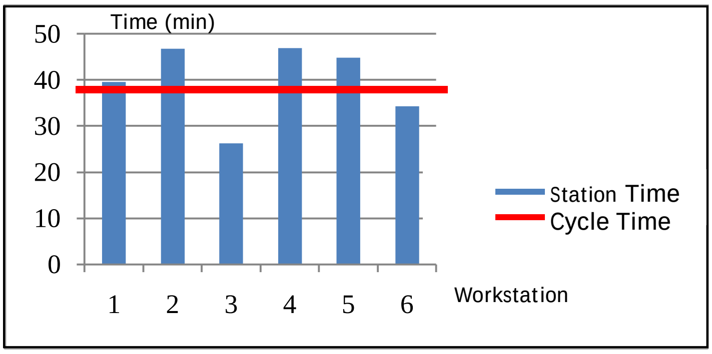


Figure 4 Yamazumi Chart of proposed straight line

The calculation of the line efficiency and smoothness index for the proposed straight line using RPW are shown as table 7 and table 8 below.

Table 7 Calculation of straight line efficiency

Workstation	Station Time (min)	Operator	Idle Time (min)	Line Efficiency
1	39,52	1	8,48	82,3%
2	46,74	1	1,26	97,4%
3	26,20	1	21,80	54,6%
4	46,92	1	1,08	97,8%
5	44,84	1	3,16	93,4%
6	34,32	1	13,68	71,5%
Average			8,24	82,8%

Table 8 Calculation of smoothness index for straight line

Operator	STi	$(STmax-STi)^2$
1	39,52	54,76
2	46,74	0,03
3	26,2	429,32
4	46,92	0,00
5	44,84	4,33
6	34,32	158,76
Total		647,20
Smoothness Index		25,44

Below is the calculation of Balance Delay:

$$BD = \frac{(6)(46{,}92) - 238{,}82}{(6)(46{,}92)} x\ 100\%$$

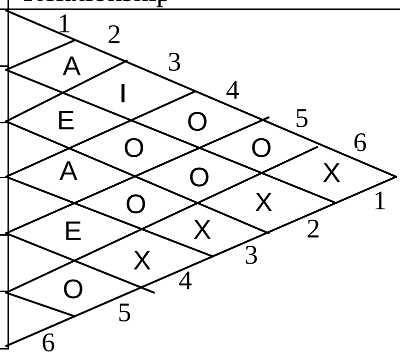
$$BD = 15{,}2\%$$

It shows that the line efficiency of the proposed line is higher than the line efficiency of current line and the balance delay of the proposed line is lower than the balance delay of the current line. The balance delay has been decreased to 15,2%. It means the bottleneck or idle time will be reduced.

It could be beneficial to design the layout of straight line balancing. The Activity relationship chart is employed for designing the layout. The ARC is shown as table 9 below.

Table 9. ARC of straight line balancing

NO	Facility	Relationship
1	Workstation 1	
2	Workstation 2	
3	Workstation 3	
4	Workstation 4	
5	Workstation 5	
6	Workstation 6	



Below is the dimensionless block diagram (layout) for straight line balancing.

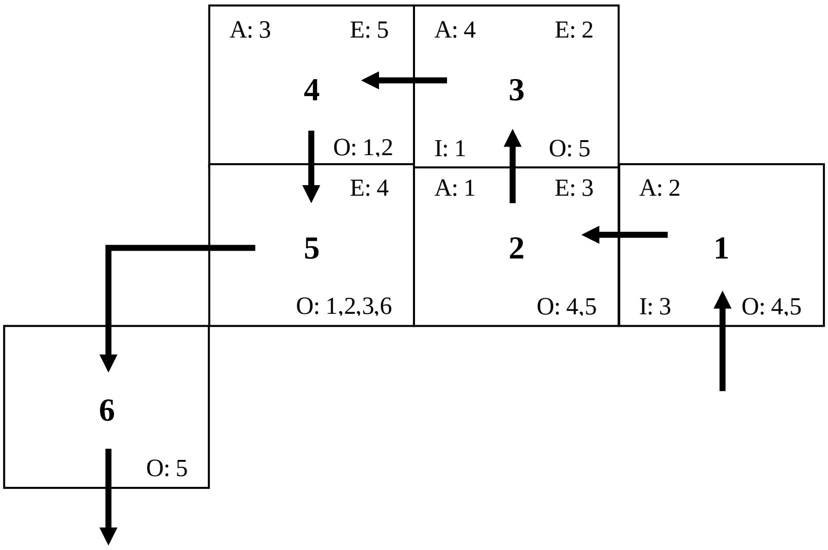


Figure 5. Dimensionless block diagram of straight line balancing

C. Proposed U-Shaped Line using Critical Tasks Method

To propose the U-shaped line flow of the line balancing is employed the Critical Tasks Method (CTM). The details calculation of CTM is shown as Appendix 4. The example of calculating backward and forward weight for Q_1 is.

Backward:

$$\sum \begin{matrix} Q1, Q3, Q5, Q6, Q8, Q9, Q10, Q13, Q14, Q16, Q17, Q19, Q21, Q23, Q24, Q25, Q27 \\ Q29, Q30, Q31, Q33, Q34, Q35, Q36, Q37, Q38, Q41, Q42, Q43, Q44, Q46, Q47 \end{matrix}$$

=0,92+2,44+1,84+2,76+0,36+2,01+7,74+5,19+0,84+1,52+11,72+4,74+0,63+0,50+1,40+2,63+10,09+1,92+3,87+3,64+4,93+2,65+3,01+6,94+2,41+7,95+13,31+1,93+5,60+2,79+1,77+1,41 = 121,43

Forward: Q1 = 0,92

The work arrangement of each station can be seen as table 10 below.

Table 10. Proposed work arrangement of u-shaped line (CTM)

Workstation	Operation	Workstation Time (min)	Number of operator
1	Q1 + Q2 + Q3 + Q4 + Q5 + Q6+ Q7 + Q8 + Q31 + Q32 + Q33 + Q34 + Q35 + Q36 + Q37 + Q38	47,58	1
2	Q9 + Q10 + Q39 + Q40 + Q41 + Q42 + Q43 + Q44 + Q45 + Q46 + Q47	47,75	1
3	Q11 + Q12 + Q13 + Q17 + Q19 + Q20 + Q21 + Q23 + Q24 + Q25 +Q29 + Q30	47,85	1
4	Q14 + Q15 + Q16 + Q18	47,86	1
5	Q26 + Q27 + Q28 + Q22	47,79	1
Average		238,82	5

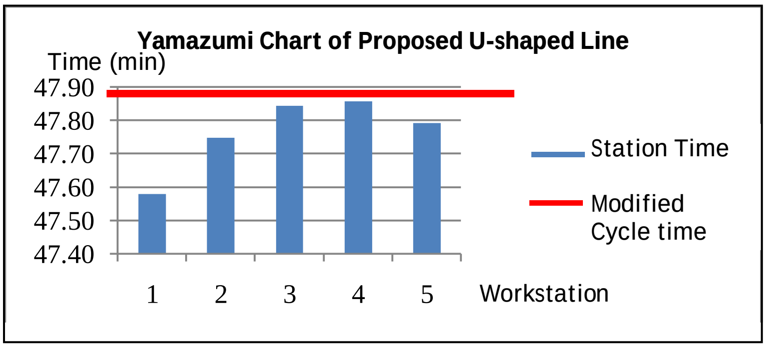


Figure 6. Yamazumi chart of proposed u-shaped line

The calculation of the line efficiency and smoothness index for the proposed U-shaped line using CTM are shown as table 11 and table 12 below.

Table 11. Calculation of u-shaped Efficiency

Work Station	Station Time (min)	Number of Operator	Idle Time (min)	Line Efficiency
1	47,58	1	0,30	99,37%
2	47,75	1	0,13	99,73%
3	47,85	1	0,03	99,93%
4	47,86	1	0,02	99,95%
5	47,79	1	0,09	99,82%
Average			0,12	99,76%

Table 12. Calculation of Smoothness Index for U-Shaped Line

Work Station	STi	$(STmax-STi)^2$
1	47,58	0,077
2	47,75	0,012
3	47,85	0,000
4	47,86	0,000
5	47,79	0,004
Total		0,093
Smoothness Index		0,305

Below is the calculation of Balance Delay of proposed u-shaped line.

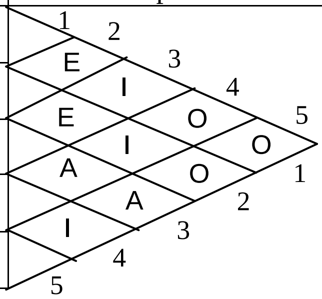
$$BD = \frac{(5)(47{,}86) - 238{,}82}{(6)(47{,}86)} x\ 100\%$$

$$BD = 0{,}2\%$$

It shows that the line efficiency of the proposed line using CTM is the highest. The balance delay is very small.. Thus, there is no bottleneck on bodyshop.

The table of ARC for u-shaped line balancing is shown as table 13 below.

Table 13 ARC of u-shaped line balancing

NO	Facility	Relationship
1	Workstation 1	
2	Workstation 2	
3	Workstation 3	
4	Workstation 4	
5	Workstation 5	

Dimensionless block diagram is the layout of proposed u-shaped line balancing.

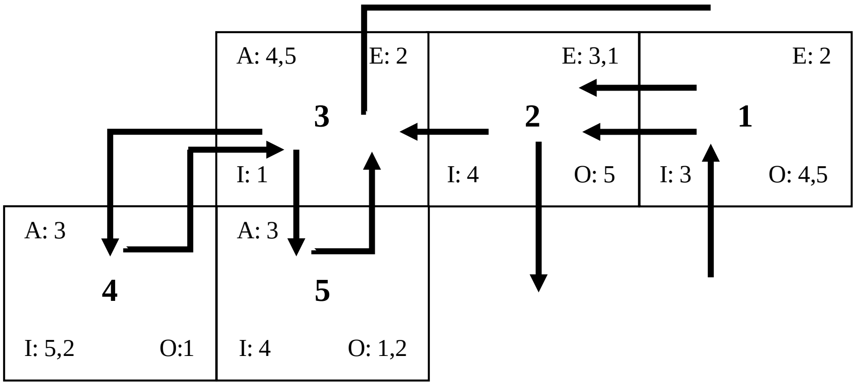


Figure 7. Dimensionless block diagram of straight line balancing

D. Simulation

In order to conduct the further study of the current and proposed line, the simulation is performed using Promodel. All simulation models are verify and valid. Model validation is tested by using paired-t (benferroni approach).

For the current condition, model validation is tested by using paired-t (comparing with actual system of bodyshop). It is the calculation of paired-t confidence intervals for the current line.

Comparing $\mu_{(A\text{-}C)}$: α =0.05 ⟶ The approximate 95% confidence interval:

$hw = \frac{(t_{22,0.05})s_{(A-C)}}{\sqrt{n}}$ $\bar{x}_{(A-C)} - hw \le \mu_{(A-C)} \le \bar{x}_{(A-C)} + hw$

$hw = \frac{(1.717)0.95}{\sqrt{23}}$ $0.43 - 0.56 \le \mu_{(A-C)} \le 0.43 + 0.56$

hw = 0.56 unit per hour $-0.12 \le \mu_{(A-C)} \le 0.99$

Given that the confidence interval about $\mu_{(A-C)}$ includes zero, it is concluded that there is no significant difference in the mean throughput produced by Actual System (μ_A) and Current Line in ProModel (μ_C). Thus, the model of current line in ProModel is right (validation and verification). There are 7.48 finished repair vehicles that are found in the finished stall. This is the output of current line in the simulation.

For the straight line using RPW, there are three model system designs; system 1 - 15 operators (station 1= 2opt, station 2= 3opt, station 3= 2opt, station 4= 3opt, station 5= 3opt, station 6= 2opt), system 2 - 16 operators (station 1= 2opt, station 2= 3opt, station 3= 2opt, station 4= 3opt, station 5= 3opt, station 6= 3opt), and system 3 - 15 operators (station 1= 3opt, station 2= 3opt, station 3= 2opt, station 4= 3opt, station 5= 3opt, station 6= 2opt). Using the benferroni approach to compare these systems. Below is the calculation of paired-t confidence intervals.

- Comparing $\mu_{(1-2)}$: $\alpha_{1=}$ 0.02 ⟶ The approximate 98% confidence interval:
  $hw = \frac{(t_{22,0.01})s_{(1-2)}}{\sqrt{n}}$ $\bar{x}_{(1-2)} - hw \leq \mu_{(1-2)} \leq \bar{x}_{(1-2)} + hw$
  $hw = \frac{(2.508)0.73}{\sqrt{23}}$ $-0.48 - 0.38 \leq \mu_{(1-2)} \leq -0.48 + 0.38$
  hw = 0.38 unit per hour $-0.86 \leq \mu_{(1-2)} \leq -0.10$
- Comparing $\mu_{(1-3)}$: $\alpha_{2=}$ 0.02 ⟶ The approximate 98% confidence interval:
  $hw = \frac{(t_{22,0.01})s_{(1-3)}}{\sqrt{n}}$ $\bar{x}_{(1-3)} - hw \leq \mu_{(1-3)} \leq \bar{x}_{(1-3)} + hw$
  $hw = \frac{(2.508)1.12}{\sqrt{23}}$ $-0.91 - 0.59 \leq \mu_{(1-3)} \leq -0.91 + 0.59$
  hw = 0.59 unit per hour $-1.50 \leq \mu_{(1-3)} \leq -0.32$
- Comparing $\mu_{(2-3)}$: α_1 = 0.02 ⟶ The approximate 98% confidence interval:
  $hw = \frac{(t_{22,0.01})s_{(2-3)}}{\sqrt{n}}$ $\bar{x}_{(2-3)} - hw \leq \mu_{(2-3)} \leq \bar{x}_{(2-3)} + hw$
  $hw = \frac{(2.508)0.84}{\sqrt{23}}$ $-0.43 - 0.44 \leq \mu_{(2-3)} \leq -0.43 + 0.44$
  hw = 0.44 unit per hour $-0.88 \leq \mu_{(2-3)} \leq 0.01$

Based on these results, the System 1 is the least favorable with respect to the mean throughtput while System 2 and System 3 are the most favorable with respect to mean throughput. Thus, the recommendation is implementing the System 3 in place of the System 2 because System 3 was the boss's idea.

Model validation is tested by using paired-t (comparing with the calculation of maximum production capacity). Below is the calculation of maximum production capacity.

P = T / C ⟶ P = 480 / 46.92 = 10.23 ≈ 10

Suppose that overall significance level is 5% (α= 0.05). Below is the calculation of paired-t confidence intervals.

- Comparing $\mu_{(C-S)}$: α =0.05 ⟶ The approximate 95% confidence interval:
  $hw = \frac{(t_{22,0.05})s_{(C-S)}}{\sqrt{n}}$ $\bar{x}_{(C-S)} - hw \leq \mu_{(C-S)} \leq \bar{x}_{(C-S)} + hw$
  $hw = \frac{(1.717)0.80}{\sqrt{23}}$ $-0.22 - 0.28 \leq \mu_{(C-S)} \leq -0.22 + 0.28$
  hw = 0.28 unit per hour $-0.50 \leq \mu_{(C-S)} \leq 0.06$

Given that the confidence interval about $\mu_{(C-S)}$ includes zero, it is concluded that there is no significant difference in the mean throughput produced by calculation of maximum production capacity (μ_C) and proposed straight line in ProModel (μ_S). Thus, the model of proposed straight line in ProModel is verify and valid. The output of proposed straight line is 11,22 finished repair vehicles in the simulation.

For the U-Shaped line, there are also three model system designs; system 1 - 15 operators (station 1= 3opt, station 2= 3opt, station 3= 3opt, station 4= 3opt, station 5= 3opt), system 2 - 14 operators (station 1= 2opt, station 2= 3opt, station 3= 3opt, station 4= 3opt, station 5= 3opt), and system 3 - 16 operators (station 1= 3opt, station 2= 3opt, station 3= 3opt, station 4= 4opt, station 5= 3opt).. Below is the calculation of paired-t confidence intervals.

- Comparing $\mu_{(1-2)}$: $\alpha_{1=}$ 0.02 ⟶ The approximate 98% confidence interval:
  $hw = \frac{(t_{22,0.01})s_{(1-2)}}{\sqrt{n}}$ $\bar{x}_{(1-2)} - hw \leq \mu_{(1-2)} \leq \bar{x}_{(1-2)} + hw$
  $hw = \frac{(2.508)1,10}{\sqrt{23}}$ $1.13 - 0.57 \leq \mu_{(1-2)} \leq 1.13 + 0.57$
  hw = 0.57 unit per hour $0.56 \leq \mu_{(1-2)} \leq 1.70$
- Comparing $\mu_{(1-3)}$: α_2 = 0.02 ⟶ The approximate 98% confidence interval:

$hw = \frac{(t_{22,0.01})s_{(1-3)}}{\sqrt{n}}$ $\bar{x}_{(1-3)} - hw \le \mu_{(1-3)} \le \bar{x}_{(1-3)} + hw$

$hw = \frac{(2.508)1,16}{\sqrt{23}}$ $-0.48 - 0.61 \le \mu_{(1-3)} \le -0.48 + 0.61$

hw = 0.61 unit per hour $-1.09 \le \mu_{(1-3)} \le 0.13$

- Comparing $\mu_{(2\text{-}3)}$: $\alpha_{1=}$ 0.02 ⟶ The approximate 98% confidence interval:

$hw = \frac{(t_{22,0.01})s_{(2-3)}}{\sqrt{n}}$ $\bar{x}_{(2-3)} - hw \le \mu_{(2-3)} \le \bar{x}_{(2-3)} + hw$

$hw = \frac{(2.508)0,89}{\sqrt{23}}$ $-1.61 - 0.47 \le \mu_{(2-3)} \le -1.61 + 0.47$

hw = 0.47 unit per hour $-2.08 \le \mu_{(2-3)} \le -1.14$

Based on these results, the System 1 is the least favorable with respect to the mean throughtput while System 2 and System 3 are the most favorable with respect to mean throughput. Model validation is tested by using paired-t (comparing with the calculation of maximum production capacity). Below is the calculation of maximum production capacity.

P = T / C ⟶ P = 480 / 46.92 = 10.23 ≈ 10

Suppose that overall significance level is 5% (α= 0.05). Below is the calculation of paired-t confidence intervals.

- Comparing $\mu_{(C\text{-}U)}$: α= 0.05 ⟶ The approximate 95% confidence interval:

$hw = \frac{(t_{22,0.05})s_{(C-U)}}{\sqrt{n}}$ $\bar{x}_{(C-U)} - hw \le \mu_{(C-U)} \le \bar{x}_{(C-U)} + hw$

$hw = \frac{(1.717)0.67}{\sqrt{23}}$ $-0.22 - 0.24 \le \mu_{(C-U)} \le -0.22 + 0.24$

hw = 0.24 unit per hour $-0.46 \le \mu_{(C-U)} \le 0.02$

Given that the confidence interval about $\mu_{(C-U)}$ includes zero, it is concluded that there is no significant difference in the mean throughput produced by calculation of maximum production capacity (μ_C) and proposed u-shaped line in ProModel (μ_U). Thus, the model of proposed u-shaped line in ProModel is right (validation and verification). There are 11,83 finished repair vehicles that are found in the finished stall. This is the output of proposed u-shaped line in the simulation.

E. Analysis

In order to prove that both proposed lines are better than the current line, the following graphs show the comparison between current and proposed line (straight line and u-shaped line).

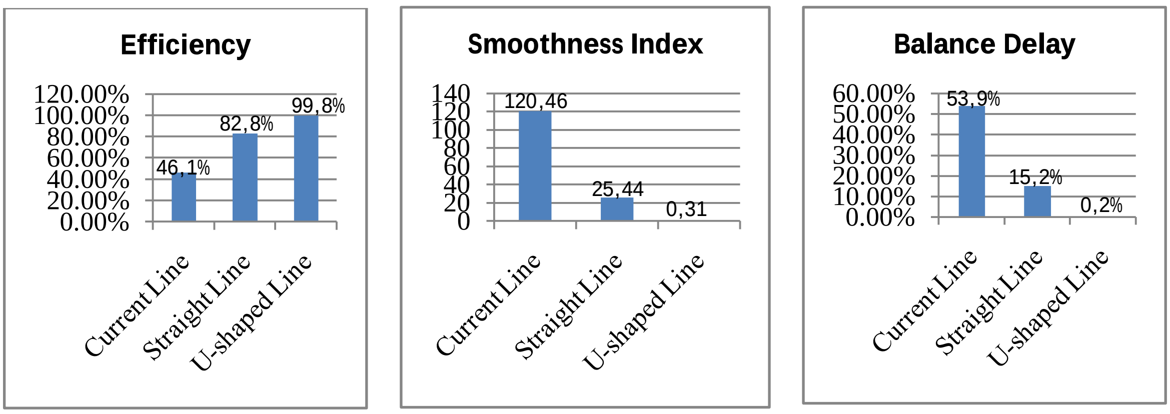


Figure 8. Comparison between Current, Straight, and U-shaped Line

Figure 8 shows a significant improvement in line efficiency, smoothness index, and balance delay. Although both proposed lines are better than the current line, the proposed u-shaped line is the best line to implement in the body shop. The proposed u-shaped line is significantly increasing the line efficiency and reducing the number of workstations. On contrast, the proposed u-shaped line is not significantly increasing the output of body shop because there is no significant difference between output of proposed straight line and output of proposed u-shaped line. This fact could happened because the main goal of proposed u-shaped line is minimizing the number of workstations. Therefore, the proposed u-shaped line is better than proposed straight line.

V. CONCLUSION

There are two ways to improve the line efficiency in the body shop; creating the accurate standard time by using time study and redesigning the assembly line through heuristic approaches (Rank Positional Weight for straight line balancing and Critical Task Method for u-shaped line balancing). The proposed u-shaped line is significantly increasing the line efficiency and reducing the number of workstations. On contrast, the proposed u-shaped line is not significantly increasing the output of body shop because there is no significant difference between output of proposed straight line and output of proposed u-shaped line. This fact could happened because the main goal of proposed u-shaped line is minimizing the number of workstations. Therefore, the proposed u-shaped line is better than proposed straight line.

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VII. APPENDICES

Appendix 1
Standard Time after Time Study

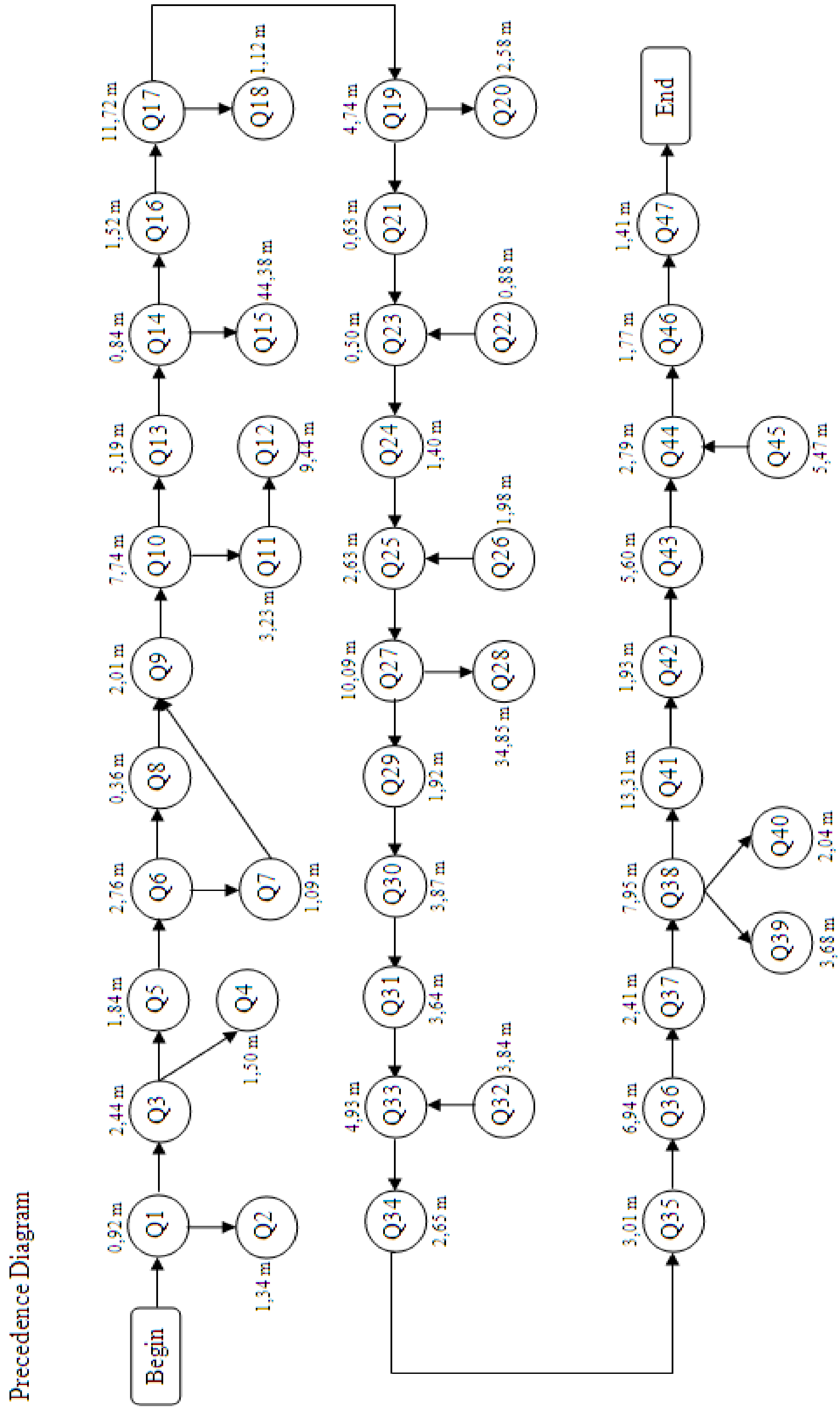
	Operation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
	1	0,76	1,22	2,2	1,28	1,54	2,31	0,83	0,27	1,84	6,8	3,2	8,26
	2	0,85	1,35	2,06	1,37	1,58	2,18	0,85	0,28	1,71	6,4	3,13	8,02
	3	0,82	1,23	2	1,35	1,7	2,39	0,9	0,28	1,9	6,59	3,29	8,15
	4	0,81	1,29	2,16	1,43	1,69	2,2	0,81	0,3	1,75	6,68	3,21	8,24
	5												
	$\bar{x}$	0,81	1,27	2,10	1,36	1,63	2,27	0,85	0,28	1,80	6,62	3,21	8,17
	S	0,04	0,06	0,09	0,06	0,08	0,10	0,04	0,01	0,09	0,17	0,06	0,11
Normality Test	α	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
	p-value	0,56	0,41	0,59	0,74	0,25	0,44	0,56	0,23	0,64	0,78	0,56	0,38
Uniformity Test	UCL	0,93	1,45	2,37	1,54	1,87	2,57	0,97	0,31	2,07	7,13	3,39	8,50
	LCL	0,69	1,09	1,83	1,18	1,39	1,97	0,73	0,25	1,53	6,11	3,03	7,84
	Max	0,85	1,35	2,20	1,43	1,70	2,39	0,90	0,30	1,90	6,80	3,29	8,26
	Min	0,76	1,22	2,00	1,28	1,54	2,18	0,81	0,27	1,71	6,40	3,13	8,02
Suffiency Test	∑ xi	3,24	5,09	8,42	5,43	6,51	9,08	3,39	1,13	7,20	26,47	12,83	32,67
	(∑ xi)^2	10,50	25,91	70,90	29,48	42,38	82,45	11,49	1,28	51,84	700,66	164,61	1067,33
	∑ xi^2	2,63	6,49	17,75	7,38	10,61	20,64	2,88	0,32	12,98	175,25	41,17	266,87
	N	4	4	4	4	4	4	4	4	4	4	4	4
	N'	3	3	3	3	3	3	3	3	3	1	1	1
Standard Time	PR	1,03	0,96	1,05	1,00	1,03	1,08	1,11	1,11	1,02	1,03	0,94	1,05
	NT	0,83	1,22	2,21	1,36	1,68	2,45	0,94	0,31	1,84	6,82	3,02	8,58
	Allowance	0,10	0,10	0,11	0,10	0,10	0,13	0,15	0,15	0,10	0,14	0,07	0,10
	ST	0,92	1,34	2,44	1,50	1,84	2,76	1,09	0,36	2,01	7,74	3,23	9,44

	Operation	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
	1	4,43	0,69	45,12	1,34	9,88	1,01	4,12	2,32	0,53	0,79	0,42	1,16
	2	4,51	0,7	42,8	1,27	9,79	0,95	4,08	2,47	0,56	0,74	0,45	1,2
	3	4,74	0,74	44,72	1,41	10,09	0,97	4,31	2,43	0,6	0,79	0,4	1,2
	4	4,73	0,76	43,83	1,39	9,83	1,04	4,24	2,28	0,55	0,83	0,44	1,19
	5							4,27	2,28	0,54	0,73	0,46	1,28
	$\bar{x}$	4,60	0,72	44,12	1,35	9,90	0,99	4,20	2,36	0,56	0,78	0,43	1,21
	S	0,16	0,03	1,03	0,06	0,13	0,04	0,10	0,09	0,03	0,04	0,02	0,04
Normality Test	α	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
	p-value	0,21	0,45	0,62	0,53	0,20	0,69	0,42	0,19	0,36	0,41	0,74	0,12
Uniformity Test	UCL	5,08	0,81	47,21	1,53	10,29	1,11	4,50	2,63	0,65	0,90	0,49	1,33
	LCL	4,12	0,63	41,03	1,17	9,51	0,87	3,90	2,09	0,47	0,66	0,37	1,09
	Max	4,74	0,76	45,12	1,41	10,09	1,04	4,31	2,47	0,60	0,83	0,46	1,28
	Min	4,43	0,69	42,80	1,27	9,79	0,95	4,08	2,28	0,53	0,73	0,40	1,16
Suffiency Test	∑ xi	18,41	2,89	176,47	5,41	39,59	3,97	21,02	11,78	2,78	3,88	2,17	6,03
	(∑ xi)^2	338,93	8,35	31141,66	29,27	1567,37	15,76	441,84	138,77	7,73	15,05	4,71	36,36
	∑ xi^2	84,81	2,09	7788,60	7,33	391,90	3,95	88,41	27,79	1,55	3,02	0,94	7,28
	N	4	4	4	4	4	4	5	5	5	5	5	5
	N'	2	3	1	3	1	2	1	2	4	4	4	2
Standard Time	PR	1,03	1,05	0,94	1,03	1,05	1,02	1,03	1,00	1,02	1,03	1,05	1,05
	NT	4,74	0,76	41,47	1,39	10,40	1,01	4,33	2,36	0,57	0,80	0,45	1,27
	Allowance	0,10	0,12	0,07	0,09	0,13	0,11	0,10	0,10	0,11	0,09	0,12	0,11
	ST	5,19	0,84	44,38	1,52	11,72	1,12	4,74	2,58	0,63	0,88	0,50	1,40

	Operation	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36
	1	2,38	1,76	8,04	35,3	1,77	3,29	2,98	3,47	4,06	2,16	2,61	6,32
	2	2,23	1,85	8,13	34,5	1,63	3,13	3,09	3,22	4,01	2,31	2,67	5,93
	3	2,27	1,89	8,25	33,97	1,82	3,39	3,07	3,58	4,18	2,29	2,79	6,1
	4		1,65	8,16	34,28	1,7	3,4	3,16	3,35	4,27	2,22		
	5		1,71	8,17	35,22	1,72	3,19	3,11	3,35	4,13	2,13		
	$\bar{x}$	2,29	1,77	8,15	34,65	1,73	3,28	3,08	3,39	4,13	2,22	2,69	6,12
	S	0,08	0,10	0,08	0,58	0,07	0,12	0,07	0,14	0,10	0,08	0,09	0,20
Normality Test	α	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
	p-value	0,36	0,79	0,62	0,41	0,90	0,48	0,59	0,66	0,90	0,56	0,49	0,60
Uniformity Test	UCL	2,53	2,07	8,39	36,39	1,94	3,64	3,29	3,81	4,43	2,46	2,96	6,72
	LCL	2,05	1,47	7,91	32,91	1,52	2,92	2,87	2,97	3,83	1,98	2,42	5,52
	Max	2,38	1,89	8,25	35,30	1,82	3,40	3,16	3,58	4,27	2,31	2,82	6,32
	Min	2,23	1,65	8,04	33,97	1,63	3,13	2,98	3,22	4,01	2,13	2,61	5,93
Suffiency Test	∑ xi	6,88	8,86	40,75	173,27	8,64	16,40	15,41	16,97	20,65	11,11	8,07	18,35
	(∑ xi)^2	47,33	78,50	1660,56	30022,49	74,65	268,96	237,47	287,98	426,42	123,43	65,12	336,72
	∑ xi^2	15,79	15,74	332,14	6005,87	14,95	53,85	47,51	57,67	85,33	24,71	21,73	112,32
	N	3	5	5	5	5	5	5	5	5	5	3	3
	N'	2	4	1	1	3	2	1	3	1	2	2	2
Standard Time	PR	1,02	1,02	1,11	0,94	1,00	1,05	1,06	1,03	1,06	1,06	1,02	1,02
	NT	2,34	1,81	9,05	32,57	1,73	3,44	3,26	3,49	4,38	2,35	2,74	6,24
	Allowance	0,13	0,10	0,12	0,07	0,11	0,12	0,12	0,10	0,13	0,13	0,10	0,11
	ST	2,63	1,98	10,09	34,85	1,92	3,87	3,64	3,84	4,93	2,65	3,01	6,94

	Operation	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47
	1	2,12	6,83	3,09	1,8	11,85	1,64	5,12	2,48	4,83	1,7	1,2
	2	2,25	7,18	3,3	1,84	10,9	1,78	4,79	2,39	4,7	1,82	1,17
	3	2,09	6,98	3,35	1,93	11,42	1,68	4,87	2,5	4,93	1,65	1,24
	4										1,68	1,28
	5											
	$\bar{x}$	2,15	7,00	3,25	1,86	11,39	1,70	4,93	2,46	4,82	1,71	1,22
	S	0,08	0,18	0,14	0,07	0,48	0,07	0,17	0,06	0,11	0,07	0,05
Normality Test	α	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
	p-value	0,23	0,60	0,24	0,44	0,62	0,40	0,32	0,22	0,60	0,20	0,82
Uniformity Test	UCL	2,39	7,54	3,67	2,07	12,83	1,91	5,44	2,64	5,15	1,92	1,37
	LCL	1,91	6,46	2,83	1,65	9,95	1,49	4,42	2,28	4,49	1,50	1,07
	Max	2,25	7,18	3,35	1,93	11,85	1,78	5,12	2,50	4,93	1,82	1,28
	Min	2,09	6,83	3,09	1,80	10,90	1,64	4,79	2,39	4,70	1,65	1,17
Suffiency Test	∑ xi	6,46	20,99	9,74	5,57	34,17	5,10	14,78	7,37	14,46	6,85	4,89
	(∑ xi)^2	41,73	440,58	94,87	31,02	1167,59	26,01	218,45	54,32	209,09	46,92	23,91
	∑ xi^2	13,93	146,92	31,66	10,35	389,65	8,68	72,88	18,11	69,72	11,75	5,98
	N	3	3	3	3	3	3	3	3	3	4	4
	N'	2	1	2	2	2	2	2	1	1	3	2
Standard Time	PR	1,02	1,02	1,02	1,00	1,05	1,02	1,02	1,02	1,02	0,95	1,05
	NT	2,19	7,14	3,32	1,86	11,96	1,73	5,03	2,51	4,92	1,62	1,28
	Allowance	0,10	0,11	0,11	0,10	0,11	0,11	0,11	0,11	0,11	0,09	0,10
	ST	2,41	7,95	3,68	2,04	13,31	1,93	5,60	2,79	5,47	1,77	1,41

Appendix 2
Precedence Diagram



Appendix 3
Rank Positional Weight

Operation	Std Time	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47
Q1	0,92	1																																														
Q2	1,34	1	1																																													
Q3	2,44	1		1																																												
Q4	1,50	1		1	1																																											
Q5	1,84	1		1		1																																										
Q6	2,76	1		1		1	1																																									
Q7	1,09	1		1		1	1	1																																								
Q8	0,36	1		1		1	1		1																																							
Q9	2,01	1		1		1	1	1	1	1																																						
Q10	7,74	1		1		1	1	1	1	1	1																																					
Q11	3,23	1		1		1	1	1	1	1	1	1																																				
Q12	9,44	1		1		1	1	1	1	1	1	1	1																																			
Q13	5,19	1		1		1	1	1	1	1	1			1																																		
Q14	0,84	1		1		1	1	1	1	1	1			1	1																																	
Q15	44,38	1		1		1	1	1	1	1	1			1	1	1																																
Q16	1,52	1		1		1	1	1	1	1	1			1	1		1																															
Q17	11,72	1		1		1	1	1	1	1	1			1	1		1	1																														
Q18	1,12	1		1		1	1	1	1	1	1			1	1		1	1	1																													
Q19	4,74	1		1		1	1	1	1	1	1			1	1		1	1		1																												
Q20	2,58	1		1		1	1	1	1	1	1			1	1		1	1		1	1																											
Q21	0,63	1		1		1	1	1	1	1	1			1	1		1	1		1		1																										
Q22	0,88																						1																									
Q23	0,50	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1																								
Q24	1,40	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1																							
Q25	2,63	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1																					
Q26	1,98																										1																					
Q27	10,09	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1																				
Q28	34,85	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1	1																			
Q29	1,92	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1																		
Q30	3,87	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1																	
Q31	3,64	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1																
Q32	3,84																																1															
Q33	4,93	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1														
Q34	2,65	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1													
Q35	3,01	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1												
Q36	6,94	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1											
Q37	2,41	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1										
Q38	7,95	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1									
Q39	3,68	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1								
Q40	2,04	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		1							
Q41	13,31	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			1						
Q42	1,93	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			1	1					
Q43	5,60	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			1	1	1				
Q44	2,79	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			1	1	1	1	1		
Q45	5,47																																													1		
Q46	1,77	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	
Q47	1,41	1		1		1	1	1	1	1	1			1	1		1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1
Weight		226,66	1,34	224,41	1,50	220,47	218,63	215,52	214,79	214,43	212,42	12,66	9,44	192,02	186,83	44,38	141,61	140,09	1,12	127,26	2,58	119,94	120,18	119,30	118,80	117,40	119,37	114,77	34,85	69,83	67,91	64,04	64,24	60,40	55,48	52,83	49,82	42,88	40,47	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41

Following table shows how the combination is determined after having RPW

Workstation	Work Element	PW	Immediate Predecessor	Std Time	Number of Operator	Cummulative per workstation	Unassigned per Workstation
1	Q1	226,66		0,92	1	39,52	8,48
1	Q3	224,41	Q1	2,44	1	39,52	8,48
1	Q5	220,47	Q3	1,50	1	39,52	8,48
1	Q6	218,63	Q5	2,76	1	39,52	8,48
1	Q7	215,52	Q6	1,09	1	39,52	8,48
1	Q8	214,79	Q6	0,36	1	39,52	8,48
1	Q9	214,43	Q7, Q8	2,01	1	39,52	8,48
1	Q10	212,42	Q9	7,74	1	39,52	8,48
1	Q13	192,02	Q10	5,19	1	39,52	8,48
2	Q14	186,83	Q13	0,84	1	46,74	1,26
2	Q16	141,61	Q14	1,52	1	46,74	1,26
3	Q17	140,09	Q16	11,72	1	26,2	21,8
3	Q19	127,26	Q17	4,74	1	26,2	21,8
3	Q22	120,18		0,88	1	26,2	21,8
3	Q21	119,94	Q19	0,63	1	26,2	21,8
4	Q26	119,37		1,98	1	46,92	1,08
3	Q23	119,3	Q21, Q22	0,50	1	26,2	21,8
3	Q24	118,8	Q23	1,40	1	26,2	21,8
3	Q25	117,4	Q24, Q26	2,63	1	26,2	21,8
4	Q27	114,77	Q25	10,09	1	46,92	1,08
5	Q29	69,83	Q27	1,92	1	44,84	3,16
5	Q30	67,91	Q29	3,87	1	44,84	3,16
5	Q32	64,24		3,84	1	44,84	3,16
5	Q31	64,04	Q30	3,64	1	44,84	3,16
5	Q33	60,4	Q31, Q32	4,93	1	44,84	3,16
5	Q34	55,48	Q33	2,65	1	44,84	3,16
5	Q35	52,83	Q34	3,01	1	44,84	3,16
5	Q36	49,82	Q35	6,94	1	44,84	3,16
2	Q15	44,38	Q14	44,38	1	46,74	1,26
5	Q37	42,88	Q36	2,41	1	44,84	3,16
5	Q38	40,47	Q37	7,95	1	44,84	3,16
4	Q28	34,85	Q27	34,85	1	46,92	1,08
6	Q41	26,81	Q38	13,31	1	34,32	13,68
6	Q42	13,5	Q41	1,93	1	34,32	13,68
1	Q11	12,66	Q10	3,23	1	39,52	8,48
6	Q43	11,57	Q42	5,60	1	34,32	13,68
6	Q45	11,45		5,47	1	34,32	13,68
1	Q12	9,44	Q11	9,44	1	39,52	8,48
6	Q44	5,97	Q43, Q45	2,79	1	34,32	13,68
5	Q39	3,68	Q38	3,68	1	44,84	3,16
6	Q46	3,18	Q44	1,77	1	34,32	13,68
3	Q20	2,58	Q19	2,58	1	26,2	21,8
6	Q40	2,04	Q38	2,04	1	34,32	13,68
1	Q4	1,5	Q3	1,50	1	39,52	8,48
6	Q47	1,41	Q46	1,41	1	34,32	13,68
1	Q2	1,34	Q1	1,34	1	39,52	8,48
3	Q18	1,12	Q17	1,12	1	26,2	21,8

Appendix 4
Critical Task Method

	Task Number	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23
1	Backward Weight	121,43	1,34	120,51	1,50	118,08	116,24	114,21	113,48	113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight	0,92	2,25	3,35	4,85	5,19	7,95	9,03	8,31	10,32	18,06	21,28	30,72	23,24	24,09	68,46	25,61	37,32	38,44	42,06	44,64	42,69	0,88	43,20
2	Backward Weight		1,34	120,51	1,50	118,08	116,24	114,21	113,48	113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight		1,34	2,44	3,93	4,27	7,03	8,12	7,39	9,40	17,14	20,37	29,80	22,33	23,17	67,55	24,69	36,41	37,52	41,14	43,73	41,78	0,88	42,28
3	Backward Weight		1,34		1,50	118,08	116,24	114,21	113,48	113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight		1,34		1,50	1,84	4,60	5,68	4,95	6,96	14,70	17,93	27,37	19,89	20,73	65,11	22,25	33,97	35,09	38,71	41,29	39,34	0,88	39,84
4	Backward Weight		1,34		1,50		116,24	114,21	113,48	113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight		1,34		1,50		2,76	3,84	3,12	5,13	12,87	16,09	25,53	18,05	18,90	63,27	20,42	32,13	33,25	36,87	39,45	37,50	0,88	38,00
5	Backward Weight		1,34		1,50			114,21	113,48	113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight		1,34		1,50			1,09	0,36	2,37	10,11	13,34	22,77	15,30	16,14	60,51	17,66	29,37	30,49	34,11	36,69	34,74	0,88	35,25
6	Backward Weight		1,34		1,50				113,48	113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight		1,34		1,50				0,36	2,37	10,11	13,34	22,77	15,30	16,14	60,51	17,66	29,37	30,49	34,11	36,69	34,74	0,88	35,25
7	Backward Weight		1,34		1,50					113,12	111,11	12,66	9,44	103,37	98,19	44,38	97,34	95,82	1,12	84,11	2,58	79,37	79,62	78,74
	Forward Weight		1,34		1,50					2,01	9,75	12,98	22,41	14,94	15,78	60,16	17,30	29,02	30,13	33,75	36,34	34,39	0,88	34,89
8	Backward Weight		1,34		1,50					111,72	109,71	12,66	9,44	101,97	96,78	44,38	95,94	94,42	1,12	82,70	2,58	77,96	78,21	77,33
	Forward Weight		1,34		1,50					2,01	9,75	12,98	22,41	14,94	15,78	60,16	17,30	29,02	30,13	33,75	36,34	34,39	0,88	34,89
9	Backward Weight		1,34		1,50					109,94	107,93	12,66	9,44	100,19	95,00	44,38	94,16	92,64	1,12	80,93	2,58	76,19	76,44	75,56
	Forward Weight		1,34		1,50					2,01	9,75	12,98	22,41	14,94	15,78	60,16	17,30	29,02	30,13	33,75	36,34	34,39	0,88	34,89
10	Backward Weight		1,34		1,50						107,93	12,66	9,44	100,19	95,00	44,38	94,16	92,64	1,12	80,93	2,58	76,19	76,44	75,56
	Forward Weight		1,34		1,50						7,74	10,97	20,40	12,93	13,77	58,15	15,29	27,01	28,12	31,74	34,33	32,38	0,88	32,88
11	Backward Weight		1,34		1,50							12,66	9,44	100,19	95,00	44,38	94,16	92,64	1,12	80,93	2,58	76,19	76,44	75,56
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
12	Backward Weight		1,34		1,50							12,66	9,44	97,40	92,21	44,38	91,37	89,85	1,12	78,13	2,58	73,40	73,64	72,76
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
13	Backward Weight		1,34		1,50							12,66	9,44	91,80	86,62	44,38	85,77	84,25	1,12	72,54	2,58	67,80	68,05	67,17
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
14	Backward Weight		1,34		1,50							12,66	9,44	89,87	84,69	44,38	83,84	82,32	1,12	70,61	2,58	65,87	66,12	65,24
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
15	Backward Weight		1,34		1,50							12,66	9,44	76,56	71,37	44,38	70,53	69,01	1,12	57,30	2,58	52,56	52,80	51,93
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
16	Backward Weight		1,34		1,50							12,66	9,44	76,56	71,37	44,38	70,53	69,01	1,12	57,30	2,58	52,56	52,80	51,93
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
17	Backward Weight		1,34		1,50							12,66	9,44	76,56	71,37	44,38	70,53	69,01	1,12	57,30	2,58	52,56	52,80	51,93
	Forward Weight		1,34		1,50							3,23	12,66	5,19	6,03	50,41	7,55	19,27	20,38	24,00	26,59	24,64	0,88	25,14
18	Backward Weight		1,34		1,50							12,66	9,44		71,37	44,38	70,53	69,01	1,12	57,30	2,58	52,56	52,80	51,93
	Forward Weight		1,34		1,50							3,23	12,66		0,84	45,22	2,36	14,08	15,20	18,81	21,40	19,45	0,88	19,95
19	Backward Weight		1,34		1,50							12,66	9,44			44,38	70,53	69,01	1,12	57,30	2,58	52,56	52,80	51,93
	Forward Weight		1,34		1,50							3,23	12,66			44,38	1,52	13,23	14,35	17,97	20,56	18,60	0,88	19,11
20	Backward Weight		1,34		1,50							12,66	9,44			44,38		69,01	1,12	57,30	2,58	52,56	52,80	51,93
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59
21	Backward Weight		1,34		1,50							12,66	9,44			44,38		61,06	1,12	49,35	2,58	44,61	44,86	43,98
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59
22	Backward Weight		1,34		1,50							12,66	9,44			44,38		61,06	1,12	49,35	2,58	44,61	44,86	43,98
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59
23	Backward Weight		1,34		1,50							12,66	9,44			44,38		58,66	1,12	46,94	2,58	42,21	42,45	41,57
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59

	Task Number	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47
1	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	44,60	47,23	1,98	57,31	92,16	59,23	63,10	66,74	3,84	71,67	74,31	77,32	84,27	86,67	94,62	98,30	96,66	107,93	109,86	115,46	118,25	5,47	120,02	121,43
2	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	43,68	46,31	1,98	56,40	91,25	58,32	62,19	65,83	3,84	70,75	73,40	76,41	83,35	85,76	93,70	97,38	95,74	107,01	108,94	114,54	117,33	5,47	119,11	120,51
3	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	41,25	43,87	1,98	53,96	88,81	55,88	59,75	63,39	3,84	68,31	70,96	73,97	80,91	83,32	91,27	94,95	93,30	104,58	106,51	112,10	114,90	5,47	116,67	118,08
4	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	39,41	42,04	1,98	52,12	86,97	54,04	57,91	61,55	3,84	66,48	69,12	72,13	79,07	81,48	89,43	93,11	91,46	102,74	104,67	110,27	113,06	5,47	114,83	116,24
5	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	36,65	39,28	1,98	49,36	84,22	51,29	55,15	58,79	3,84	63,72	66,37	69,38	76,32	78,72	86,67	90,35	88,71	99,98	101,91	107,51	110,30	5,47	112,07	113,48
6	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	36,65	39,28	1,98	49,36	84,22	51,29	55,15	58,79	3,84	63,72	66,37	69,38	76,32	78,72	86,67	90,35	88,71	99,98	101,91	107,51	110,30	5,47	112,07	113,48
7	Backward Weight	78,23	76,83	78,81	74,20	34,85	64,12	62,20	58,33	58,53	54,69	49,76	47,11	44,11	37,16	34,76	3,68	2,04	26,81	13,50	11,57	5,97	11,45	3,18	1,41
	Forward Weight	36,29	38,92	1,98	49,01	83,86	50,93	54,80	58,44	3,84	63,36	66,01	69,02	75,96	78,37	86,31	89,99	88,35	99,62	101,55	107,15	109,94	5,47	111,72	113,12
8	Backward Weight	76,83	75,42	77,40	72,80	34,85	62,71	60,79	56,92	57,12	53,28	48,36	45,71	42,70	35,76	33,35	3,68	2,04	25,40	12,09	10,16	4,57	10,04	1,77	
	Forward Weight	36,29	38,92	1,98	49,01	83,86	50,93	54,80	58,44	3,84	63,36	66,01	69,02	75,96	78,37	86,31	89,99	88,35	99,62	101,55	107,15	109,94	5,47	111,72	
9	Backward Weight	75,05	73,65	75,63	71,02	34,85	60,94	59,01	55,15	55,35	51,51	46,58	43,93	40,92	33,98	31,58	3,68	2,04	23,63	10,32	8,39	2,79	8,26		
	Forward Weight	36,29	38,92	1,98	49,01	83,86	50,93	54,80	58,44	3,84	63,36	66,01	69,02	75,96	78,37	86,31	89,99	88,35	99,62	101,55	107,15	109,94	5,47		
10	Backward Weight	75,05	73,65	75,63	71,02	34,85	60,94	59,01	55,15	55,35	51,51	46,58	43,93	40,92	33,98	31,58	3,68	2,04	23,63	10,32	8,39	2,79	8,26		
	Forward Weight	34,28	36,91	1,98	47,00	81,85	48,92	52,78	56,43	3,84	61,35	64,00	67,01	73,95	76,35	84,30	87,98	86,34	97,61	99,54	105,14	107,93	5,47		
11	Backward Weight	75,05	73,65	75,63	71,02	34,85	60,94	59,01	55,15	55,35	51,51	46,58	43,93	40,92	33,98	31,58	3,68	2,04	23,63	10,32	8,39	2,79	8,26		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56	80,24	78,60	89,87	91,80	97,40	100,19	5,47		
12	Backward Weight	72,26	70,86	72,83	68,23	34,85	58,14	56,22	52,35	52,55	48,71	43,79	41,14	38,13	31,19	28,78	3,68	2,04	20,84	7,53	5,60		5,47		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56	80,24	78,60	89,87	91,80	97,40		5,47		
13	Backward Weight	66,66	65,26	67,24	62,63	34,85	52,55	50,63	46,76	46,96	43,12	38,19	35,54	32,53	25,59	23,19	3,68	2,04	15,24	1,93			5,47		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56	80,24	78,60	89,87	91,80			5,47		
14	Backward Weight	64,73	63,33	65,31	60,70	34,85	50,62	48,70	44,83	45,03	41,19	36,26	33,61	30,61	23,66	21,26	3,68	2,04	13,31				5,47		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56	80,24	78,60	89,87				5,47		
15	Backward Weight	51,42	50,02	52,00	47,39	34,85	37,30	35,38	31,52	31,72	27,88	22,95	20,30	17,29	10,35	7,95	3,68	2,04					5,47		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56	80,24	78,60					5,47		
16	Backward Weight	51,42	50,02	52,00	47,39	34,85	37,30	35,38	31,52	31,72	27,88	22,95	20,30	17,29	10,35	7,95		2,04					5,47		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56		78,60					5,47		
17	Backward Weight	51,42	50,02	52,00	47,39	34,85	37,30	35,38	31,52	31,72	27,88	22,95	20,30	17,29	10,35	7,95							5,47		
	Forward Weight	26,54	29,17	1,98	39,26	74,11	41,18	45,05	48,69	3,84	53,61	56,26	59,27	66,21	68,62	76,56							5,47		
18	Backward Weight	51,42	50,02	52,00	47,39	34,85	37,30	35,38	31,52	31,72	27,88	22,95	20,30	17,29	10,35	7,95							5,47		
	Forward Weight	21,36	23,98	1,98	34,07	68,92	35,99	39,86	43,50	3,84	48,42	51,07	54,08	61,02	63,43	71,37							5,47		
19	Backward Weight	51,42	50,02	52,00	47,39	34,85	37,30	35,38	31,52	31,72	27,88	22,95	20,30	17,29	10,35	7,95							5,47		
	Forward Weight	20,51	23,14	1,98	33,23	68,08	35,15	39,01	42,65	3,84	47,58	50,23	53,24	60,18	62,58	70,53							5,47		
20	Backward Weight	51,42	50,02	52,00	47,39	34,85	37,30	35,38	31,52	31,72	27,88	22,95	20,30	17,29	10,35	7,95							5,47		
	Forward Weight	18,99	21,62	1,98	31,71	66,56	33,63	37,49	41,14	3,84	46,06	48,71	51,72	58,66	61,06	69,01							5,47		
21	Backward Weight	43,48	42,07	44,05	39,44	34,85	29,36	27,44	23,57	23,77	19,93	15,00	12,36	9,35	2,41								5,47		
	Forward Weight	18,99	21,62	1,98	31,71	66,56	33,63	37,49	41,14	3,84	46,06	48,71	51,72	58,66	61,06								5,47		
22	Backward Weight	43,48	42,07	44,05	39,44		29,36	27,44	23,57	23,77	19,93	15,00	12,36	9,35	2,41								5,47		
	Forward Weight	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84	46,06	48,71	51,72	58,66	61,06								5,47		
23	Backward Weight	41,07	39,67	41,64	37,04		26,95	25,03	21,16	21,36	17,52	12,60	9,95	6,94									5,47		
	Forward Weight	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84	46,06	48,71	51,72	58,66									5,47		

Task Number		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47
24	Backward Weight		1,34		1,50							12,66	9,44			44,38		51,72	1,12	40,00	2,58	35,27	35,51	34,63	34,13	32,73	34,70	30,10		20,01	18,09	14,22	14,42	10,58	5,66	3,01										5,47		
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84	46,06	48,71	51,72										5,47		
25	Backward Weight		1,34		1,50							12,66	9,44			44,38		48,71	1,12	36,99	2,58	32,26	32,50	31,62	31,12	29,72	31,69	27,09		17,00	15,08	11,21	11,41	7,57	2,65											5,47		
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84	46,06	48,71											5,47		
26	Backward Weight		1,34		1,50							12,66	9,44			44,38		46,06	1,12	34,34	2,58	29,61	29,85	28,98	28,47	27,07	29,04	24,44		14,35	12,43	8,57	8,77	4,93												5,47		
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84	46,06												5,47		
27	Backward Weight		1,34		1,50							12,66	9,44			44,38		41,14	1,12	29,42	2,58	24,68	24,93	24,05	23,55	22,14	24,12	19,52		9,43	7,51	3,64	3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66			44,38		11,72	12,83	16,45	19,04	17,09	0,88	17,59	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84													5,47		
28	Backward Weight		1,34		1,50							12,66	9,44					41,14	1,12	29,42	2,58	24,68	24,93	24,05	23,55	22,14	24,12	19,52		9,43	7,51	3,64	3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66					11,72	12,83	16,45	19,04	17,09	0,88	17,59	18,99	21,62	1,98	31,71		33,63	37,49	41,14	3,84													5,47		
29	Backward Weight		1,34		1,50							12,66	9,44					37,49	1,12	25,78	2,58	21,04	21,29	20,41	19,91	18,50	20,48	15,87		5,79	3,87		3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66					11,72	12,83	16,45	19,04	17,09	0,88	17,59	18,99	21,62	1,98	31,71		33,63	37,49		3,84													5,47		
30	Backward Weight		1,34		1,50							12,66	9,44						1,12	25,78	2,58	21,04	21,29	20,41	19,91	18,50	20,48	15,87		5,79	3,87		3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12	4,74	7,32	5,37	0,88	5,87	7,28	9,90	1,98	19,99		21,91	25,78		3,84													5,47		
31	Backward Weight		1,34		1,50							12,66	9,44						1,12	21,91	2,58	17,18	17,42	16,54	16,04	14,63	16,61	12,01		1,92			3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12	4,74	7,32	5,37	0,88	5,87	7,28	9,90	1,98	19,99		21,91			3,84													5,47		
32	Backward Weight		1,34		1,50							12,66	9,44						1,12	19,99	2,58	15,25	15,50	14,62	14,12	12,71	14,69	10,09					3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12	4,74	7,32	5,37	0,88	5,87	7,28	9,90	1,98	19,99					3,84													5,47		
33	Backward Weight		1,34		1,50							12,66	9,44						1,12		2,58	15,25	15,50	14,62	14,12	12,71	14,69	10,09					3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12		2,58	0,63	0,88	1,14	2,54	5,17	1,98	15,25					3,84													5,47		
34	Backward Weight		1,34		1,50							12,66	9,44						1,12		2,58	15,25		14,62	14,12	12,71	14,69	10,09					3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12		2,58	0,63		1,14	2,54	5,17	1,98	15,25					3,84													5,47		
35	Backward Weight		1,34		1,50							12,66	9,44						1,12		2,58			14,62	14,12	12,71	14,69	10,09					3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12		2,58			0,50	1,91	4,54	1,98	14,62					3,84													5,47		
36	Backward Weight		1,34		1,50							12,66	9,44						1,12		2,58			14,62	14,12	12,71		10,09					3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12		2,58			0,50	1,91	4,54		14,62					3,84													5,47		
37	Backward Weight		1,34		1,50							12,66	9,44						1,12		2,58			4,54	4,03	2,63							3,84													5,47		
	Forward Weight		1,34		1,50							3,23	12,66						1,12		2,58			0,50	1,91	4,54							3,84													5,47		
38	Backward Weight		1,34		1,50								9,44						1,12		2,58			4,54	4,03	2,63							3,84													5,47		
	Forward Weight		1,34		1,50								9,44						1,12		2,58			0,50	1,91	4,54							3,84													5,47		
39	Backward Weight		1,34		1,50														1,12		2,58			4,54	4,03	2,63							3,84													5,47		
	Forward Weight		1,34		1,50														1,12		2,58			0,50	1,91	4,54							3,84													5,47		
40	Backward Weight		1,34		1,50														1,12		2,58			4,54	4,03	2,63							3,84															
	Forward Weight		1,34		1,50														1,12		2,58			0,50	1,91	4,54							3,84															
41	Backward Weight		1,34		1,50														1,12		2,58				4,03	2,63							3,84															
	Forward Weight		1,34		1,50														1,12		2,58				1,40	4,03							3,84															
42	Backward Weight		1,34		1,50														1,12		2,58					2,63							3,84															
	Forward Weight		1,34		1,50														1,12		2,58					2,63							3,84															
43	Backward Weight		1,34		1,50														1,12		2,58					2,63																						
	Forward Weight		1,34		1,50														1,12		2,58					2,63																						
44	Backward Weight		1,34		1,50														1,12		2,58																											
	Forward Weight		1,34		1,50														1,12		2,58																											
45	Backward Weight		1,34		1,50														1,12																													
	Forward Weight		1,34		1,50														1,12																													
46	Backward Weight		1,34																1,12																													
	Forward Weight		1,34																1,12																													
47	Backward Weight																		1,12																													
	Forward Weight																		1,12																													

Iteration	Candidate List	Assigned Task	Task Time	Station No.
1	Q1,Q47	Q1	0,92	1
2	Q3,Q47	Q3	2,44	1
3	Q5,Q47	Q5	1,84	1
4	Q6,Q47	Q6	2,76	1
5	Q7	Q7	1,09	1
6	Q8,Q47	Q8	0,36	1
7	Q9,Q47	Q47	1,41	2
8	Q9,Q46	Q46	1,77	2
9	Q9,Q44	Q9	2,01	2
10	Q10,Q44	Q10	7,74	2
11	Q13,Q44	Q44	2,79	2
12	Q13,Q43	Q43	5,60	2
13	Q13,Q42	Q42	1,93	2
14	Q13,Q41	Q41	13,31	2
15	Q39	Q39	3,68	2
16	Q40	Q40	2,04	2
17	Q13,Q38	Q13	5,19	3
18	Q14,Q38	Q14	0,84	4
19	Q16,Q38	Q16	1,52	4
20	Q17,Q38	Q38	7,95	1
21	Q28	Q28	34,85	5
22	Q17,Q37	Q37	2,41	1
23	Q17,Q36	Q36	6,94	1
24	Q17,Q35	Q35	3,01	1
25	Q17,Q34	Q34	2,65	1
26	Q17,Q33	Q33	4,93	1
27	Q15	Q15	44,38	4
28	Q17,Q31	Q31	3,64	1
29	Q17,Q30	Q17	11,72	3
30	Q19,Q30	Q30	3,87	3
31	Q19,Q29	Q29	1,92	3
32	Q19,Q27	Q19	4,74	3
33	Q22	Q22	0,88	5
34	Q21,Q27	Q21	0,63	3
35	Q26	Q26	1,98	5
36	Q23,Q27	Q27	10,09	5
37	Q11,Q12	Q11	3,23	3
38	Q12	Q12	9,44	3
39	Q45	Q45	5,47	2
40	Q23,Q25	Q23	0,50	3
41	Q24,Q25	Q24	1,40	3
42	Q32	Q32	3,84	1
43	Q25	Q25	2,63	3
44	Q20	Q20	2,58	3
45	Q4	Q4	1,50	1
46	Q2	Q2	1,34	1
47	Q18	Q18	1,12	4