Flowshop Scheduling Using Cds Algorithm, Bat Algorithm, And Tabu Search Algorithm At PT. Dynaplast Jatake

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Abstract
Production scheduling is an important process, especially in manufacturing or service industries, to allocate existing resources to make them more orderly, effective, and efficient. Production scheduling can be defined as controlling, managing, and optimizing work in a production process or manufacturing process to get optimal time. The purpose of this study is to minimize the scheduling makespan at PT. Dynaplast Jatake. The company's actual scheduling has a makespan of 4954.73, which indicates that PT. Dynaplast in its production scheduling has not been maximized and is still using the FIFO (First In First Out) method.The method used in this study is the CDS (Campbell, Dudek and Smith Algorithm), Bat Algorithm, and the Tabu Search Algorithm. In the CDS algorithm, the job sequence MF-Arrow-Wendy-ZWT-NBE has the smallest makespan of 4119.50 and a mean flow time of 3328.34. Meanwhile, in the Tabu Search Algorithm, the job sequences of Arrow-MF-Wendy-ZWT-NBE and MF-Arrow-Wendy-ZWT-NBE have the same makespan value of 4030.89. In the Bat Algorithm, the smallest makespan is 4620 seconds for the 4th bat in the order of the job Arrow - NBE - Morning Fresh (MF) - ZWT- Wendy. Based on the result, Tabu Search Algorithm is the best method of scheduling for PT. Dynaplast.

Keyword: Flowshop Scheduling, CDS Algorithm, Bat Algorithm, Tabu Search Algorithm

1. Introduction
The industry is the process of making and processing raw materials into a usable product. There are many challenges faced today to compete with competitors because of the rapid development of the industry. Therefore, the industry today must strive for better development. One of the developments that have been done is to make production scheduling more effectively so that sales can be delivered on time and do not suffer losses. PT. Dynaplast Jatake is a manufacturing company engaged in producing medium to high-quality plastics for various needs such as bottles or other necessities. PT. Dynaplast Jatake uses quality imported plastic pellets from Singapore to make all the bottled products it produces. The problem experienced by this company is implementing manual production scheduling. Often, some jobs are prioritized according to the demands of production employees. Sometimes, they have not implemented a scheduling system as part of the production system. The limitation of the problem used in this research is that the research was conducted at PT. Dynaplast Jatake by interview, direct observation, and data collection in the company, focusing on product planning with ZWT 300 gr Neck Snap, Wendy 400 ml, *Morning Fresh* 400 ml, Arrow 500 ml, and NBE 100 ml, the data used were July period data. 2020-August 2020, it is assumed that the machine condition and delivery times are always right.

This study aimed to determine the number of actual orders and the number of order planning for each product at PT. Dynaplast Jatake, knowing the company's production flow and scheduling system used and looking for the total time needed to complete orders at PT. Dynaplast Jatake, provides the most appropriate engine scheduling design proposal that can minimize the makespan and design an information system that is a simple application program that can help the production department in the scheduling process at PT. Dynaplast Jatake.

2. Literature Review
2.1. Scheduling
Scheduling is the sorting of making or working a product as a whole process is done on several machines. (Ginting, 2009).

Scheduling is a theory in which there are fundamental principles, models, techniques, and logical conclusions in the decision-making process that understand the scheduling function. Scheduling is an important process, especially in manufacturing or service industries, to allocate existing resources to be more orderly, effective, and efficient. The resources in question can be machines or workers. According to Putri Lynna A. Luthan and Syafriandi (2006), the purpose of scheduling is to formulate activity stages, determine strategies and methods, and find out critical activities.

2.2. Scheduling Classification

Scheduling classification according to the process flow or process design strategy is divided into several parts:

1. Flow Shop Scheduling

This scheduling in the production process moves in one direction and usually has a flow pattern from one machine to another sequentially. In other words, shop flow scheduling has process flow movements that move in the same order.

2. Job Shop Scheduling

This scheduling is a process of planning in which the order of production, machines, and equipment is arranged based on job requirements in a product. The flow patterns in this scheduling are different and not always in one direction

2.3. Flowshop Scheduling Characteristic

Flowshop scheduling is a continuous movement of units through a series of work stations arranged by-product (Baker, 1974):

1. Flow shop has a small variety of products but has a large production volume.
2. All jobs must go through the same sequence of operation processes and sequentially arrange the machines in series.
3. Flow shop is easy for scheduling due to the sequential flow of work.

2.4. Time Study

Taylor Frederick W. Taylor first introduced the stopwatch time study. Time measurement attempts to determine the length of work time required by an operator to complete a job (Niebel, 1988).

2.5. CDS (Campbell, Dudek, and Smith) Algorithm

The CDS algorithm is an algorithm developed from the Johnson rule algorithm. Johnson's rule is an algorithm that schedules jobs on two serial machines and aims to minimize the makespan value. This Johnson rule was developed by Campbell, Dudek, and Smith, an algorithm for scheduling multiple jobs on many machines that can generate as many scheduling alternatives as machines and choose the best to develop and implement.

2.6. Bat Algorithm

The Bat Algorithm (BA) algorithm is a metaheuristic algorithm introduced by Xin-She in 2010. A new heuristic algorithm adapted from bats' behavior looking for food and mimics the behavior of bats moving around with vibrations to know their surroundings. This algorithm is proven to be able to solve various optimization problems very well and in detail.

2.7. Tabu Search Algorithm

Tabu Search comes from Tongan, a Polynesian language used by the Island Aborigines. This metaheuristic algorithm makes the search process effective by finding the best solution at each tracking stage. The tabu search method uses the tabu list to store a set of solutions.

3. Methods

his research was conducted to examine the root of the problems experienced by PT. Dynaplast Jatake, namely the production's inability to meet all demands by making appropriate production plans using forecasting methods, aggregate and disaggregate planning, rough-cut capacity planning, material requirements planning, and capacity requirement planning.

The research begins with conducting field studies and literature studies related to flowshop scheduling, after conducting a field study, identifying PT. Dynaplast Jatake's problem to make problem formulation at PT. Dynaplast Jatake. The next step is to determine the research objectives so that research can be carried out systematically on the problem to be studied and run systematically. After determining the research objectives, collect the necessary data in the research, including the demand data for each product type. The data collected will be processed by first calculating the average, standard, and process times. After that, the data is processed using the CDS Algorithm, Bat Algorithm, and Tabu Search.

Based on the calculation results, perform data analysis and discussion results, and provide recommendations for scheduling solutions that can be applied to overcome PT. Dynaplast Jatake's problem. After that, make a scheduling program that can be used at PT. Dynaplast Jatake. Based on the analysis that has been made, draw conclusions and suggestions from the research that has been done.

4. Result and Discussion

4.1. Standard Time, Setup Time, and Processing Time

The standard time calculation is obtained by multiplying the average time by the allowance factor to add. Allowance factors include the energy expended, work attitude, work movements, eye fatigue, workplace temperature conditions, atmospheric conditions, and excellent environmental conditions. Setup time is the time required to carry out preparation activities for a work operation. Processing time is obtained from the sum of the standard time and setup time. The standard time can be seen in Table 1 below.

Table 1. Standard Time, Setup Time, and Processing Time

Job	Standard Time	Setup Time	Processing Time
		Weighing	
MF	72.79	300	372.79
NBE	71.13	300	371.13
WENDY	71.08	300	371.08
ARROW	71.83	300	371.83
ZWT	72.35	300	372.35
		Mixing	
MF	796.54	30	826.54
NBE	793.61	30	823.61
WENDY	794.46	30	824.46
ARROW	792.90	30	822.90
ZWT	800.62	30	830.62
		Blow Molding	
MF	199.98	60	259.98
NBE	147.32	60	207.32
WENDY	248.70	60	308.70
ARROW	249.67	60	309.67
ZWT	166.72	60	226.72
		Leak Tester	
MF	90.93	10	100.93
NBE	90.98	10	100.98
WENDY	91.25	10	101.25
ARROW	90.56	10	100.56
ZWT	90.51	10	100.51
		Labeling	
MF	38.23	20	58.23
NBE	37.56	20	57.56
WENDY	37.94	20	57.94
ARROW	38.10	20	58.10
ZWT	37.48	20	57.48
		Packing	
MF	12.68	60	72.68
NBE	10.64	60	70.64
WENDY	12.55	60	72.55
ARROW	12.77	60	72.77
ZWT	10.76	60	70.76

4.2. Actual Scheduling

Actual Scheduling PT. Dynaplast Jatake has a job order NBE-Wendy-MF-Arrow-ZWT can be seen in Table 2.

Table 2. Actual Scheduling PT. Dynaplast Jatake

Job	Weighing		Mixing		Blow Molding	
	Start	End	Start	End	Start	End
NBE	0	371.13	371.13	1194.74	1194.74	1402.06

WENDY	371.13	742.21	1194.74	2019.20	2019.20	2327.89
MF	742.21	1115.00	2019.20	2845.73	2845.73	3105.72
ARROW	1115.00	1486.82	2845.73	3668.64	3668.64	3978.31
ZWT	1486.82	1859.17	3668.64	4499.26	4499.26	4725.97

Job	Leak Tester		Labeling		Packing	
	Start	End	Start	End	Start	End
NBE	1402.06	1503.05	1503.05	1560.61	1560.61	1631.25
WENDY	2327.89	2429.14	2429.14	2487.07	2487.07	2559.63
MF	3105.72	3206.65	3206.65	3264.88	3264.88	3337.57
ARROW	3978.31	4078.87	4078.87	4136.98	4136.98	4209.74
ZWT	4725.97	4826.48	4826.48	4883.97	4883.97	4954.73
					Makespan	4954.73
					Mean Flow Time	3338.58

4.3. CDS Algorithm

There are five iterations in the CDS algorithm. The smallest makespan value is found in the second iteration in the order of the jobs Morning Fresh (MF) -Arrow-Wendy-ZWT-NBE. The calculation for the first to the last iteration can be seen in Table 3-7 below.

Table 3. First Iteration of CDS Algorithm

Job	K = 1 (second)	
	Weighing	Packing
ARROW	371.83	72.77
MF	372.79	72.68
WENDY	371.08	72.55
ZWT	372.35	70.76
NBE	371.13	70.64

Table 4. Second Iteration of CDS Algorithm

Job	K =2 (second)	
	Weighing +Mixing	Labeling+Packing
MF	1199.33	130.92
ARROW	1194.73	130.87
WENDY	1195.54	130.49
ZWT	1202.97	128.25
NBE	1194.74	128.20

Table 5. Third Iteration of CDS Algorithm

Job	K = 3 (second)	
	Weighing + *Mixing* + *Blow Molding*	*Leak Tester* + *Labeling* + *Packing*
MF	1459.31	231.85
WENDY	1504.24	231.73
ARROW	1504.40	231.44
NBE	1402.06	229.18
ZWT	1429.68	228.76

Table 6. Fourth Iteration of CDS Algorithm

Job	K = 4 (second)	
	Weighing + *Mixing* + *Blow Molding* + *Leak Tester*	*Blow Molding* + *Leak Tester* + *Labeling* + *Packing*
ARROW	1604.96	541.10
WENDY	1605.48	540.43

MF	1560.24	491.83
ZWT	1530.20	455.47
NBE	1503.05	436.51

Table 7. Last Iteration of CDS Algorithm

Job	K = 5 (second)	
	Weighing + *Mixing + Blow Molding + Leak Tester+ Labeling*	*Mixing +Blow Molding + Leak Tester + Labeling+ Packing*
WENDY	1663.42	1364.89
ARROW	1663.07	1364.01
MF	1618.47	1318.37
ZWT	1587.68	1286.09
NBE	1560.61	1260.12

Tabe; 8 shows a recapitulation of the CDS Algorithm results, shown in Table 8 below.

Table 8. Recapitulation of CDS Algorithm

Iteration	Makespan (second)	Mean Flowtime (second)
1	4936.46	3340.67
2	4924.34	3328.34
3	4956.39	3341.27
4	4936.46	3340.26
5	4935.72	3339.82

After the five iterations are obtained, the fifth iteration is selected in the order Wendy-Arrow- Morning Fresh (MF) -ZWT-NBE with a makespan of 4935.72 and a mean flowtime of 3339.82. The results of the 2nd iteration of the CDS Algorithm can be seen in Table 9.

Table 9. Result of Last Iteration CDS Algorithm

Job	Weighing		*Mixing*		*Blow Molding*	
	Start	End	Start	End	Start	End
WENDY	0	371.08	371.08	1195.54	1195.54	1504.24
ARROW	371.08	742.91	1195.54	2018.44	2018.44	2328.11
MF	742.91	1115.70	2018.44	2844.98	2844.98	3104.96
ZWT	1115.70	1488.05	2844.98	3675.60	3675.60	3902.32
NBE	1488.05	1859.17	3675.60	4499.21	4499.21	4706.54

Job	*Leak Tester*		*Labeling*		*Packing*	
	Start	End	Start	End	Start	End
WENDY	1504.24	1605.48	1605.48	1663.42	1663.42	1735.97
ARROW	2328.11	2428.68	2428.68	2486.78	2486.78	2559.55
MF	3104.96	3205.89	3205.89	3264.13	3264.13	3336.81
ZWT	3902.32	4002.83	4002.83	4060.31	4060.31	4131.07
NBE	4706.54	4807.52	4807.52	4865.08	4865.08	4935.72
					Makespan	4935.72
					Mean Flow Time	3339.82

4.4. Tabu Search Algorithm

The result of the Tabu Search Algorithm iteration with the smallest makespan is the job order of Wendy-Morning Fresh (MF) - Arrow- ZWT- NBE with makespan 4935.72, and the mean flow time value is 3340.55. While the second iteration of the job sequence Wendy-Arrow - Morning Fresh (MF) - ZWT-NBE has the smallest makespan value is 4935.72, and the mean flow time value is 3339.82. Candidate List Iterations 1 and 2 can be seen in Tables 10 and 11 below.

Table 10. Candidate List First Iteration

Switch	To	*Neighborhood Switch*	*Makespan*	*Mean Flow Time*
Wendy	Arrow	ARROW-WENDY-MF-ZWT-NBE	4936.46	3340.26
	MF	MF-ARROW-WENDY-ZWT-NBE	4937.42	3342.36
	ZWT	ZWT-ARROW-MF-WENDY-NBE	4936.98	3344.79
	NBE	NBE-ARROW-MF-ZWT-WENDY	5039.69	3339.19
Arrow	MF	WENDY-MF-ARROW-ZWT-NBE	4935.72	3340.55
	ZWT	WENDY-ZWT-MF-ARROW-NBE	4935.72	3342.91
	NBE	WENDY-NBE-MF-ZWT-ARROW	5040.32	3340.25
MF (*Morning Fresh*)	ZWT	WENDY-ARROW-ZWT-MF-NBE	4935.72	3340.64
	NBE	WENDY-ARROW-NBE-ZWT-MF	4991.04	3338.65
ZWT	NBE	WENDY-ARROW-MF-NBE-ZWT	4954.69	3338.42

Table 11. Candidate List Second Iteration

Switch	To	*Neighborhood Switch*	*Makespan*	*Mean Flow Time*
Wendy	MF	MF-ARROW-WENDY-ZWT-NBE	4935.72	3340.55
	Arrow	WENDY-MF-ARROW-ZWT-NBE	4936.46	3340.26
	ZWT	ZWT-MF-WENDY-ARROW-NBE	4936.98	3345.52
	NBE	NBE-MF-WENDY-ZWT-ARROW	5039.69	3339.92
Morning Fresh (MF)	*Arrow*	ARROW-WENDY-MF-ZWT-NBE	4935.72	3339.82
	ZWT	ARROW-ZWT-WENDY-MF-NBE	4935.72	3342.18
	NBE	ARROW -NBE-WENDY-ZWT-MF	4991.04	3338.80
Arrow	ZWT	ARROW-MF-ZWT-WENDY-NBE	4935.72	3342.10
	NBE	ARROW-MF-NBE-ZWT-WENDY	5040.32	3340.84
ZWT	NBE	ARROW-MF-WENDY-NBE-ZWT	4958.48	3333.22

Table 12 shows a recapitulation of the Tabu Search Algorithm results, which can be seen in Table 12 below.

Table 12. Recapitulation of Tabu List

	Time (second)		
	Iteration 0	Iteration 1	Iteration 2
Makespan	4935.72	4935.72	4935.72
Mean Flow Time	3339.82	3340.55	3339.82

4.5. Bat Algorithm

In this Bat Algorithm, the step that must be taken is to find random values of 5 jobs x 6 machines x 10 bats, namely 300 random values. The next step is to find the makespan value from the initial position and find the beta and Qi values. The makespan of the Initial Position can be seen in Table 13 below.

Table 13. Makespan of the Initial Position

i	Makespan of the Initial Position
1	4709.57
2	4891.99
3	5751.66
4	4619.95
5	6437.12
6	5132.35
7	5384.5
8	6051.02
9	5619.35
10	5583.11

The next step is to determine the speed taken from 300 random values and make a movement position from that velocity value. After creating a movement position. The next step is to create a random value from random numbers. A random value of less than 0.3 creates an effect on the withdrawal and becomes unused so that a new position will appear.

After that, find the epsilon value from the random value of the bat that was not eliminated. After the epsilon value exists. Calculate the new position from the local search. After the new position exists. Compare the makespan value of the old solution with the new solution. The solution for makespan update is the smallest makespan. The value of the Update Solution Makespan can be seen in Table 14 below.

Table 14. Makespan of Update Solution

Initial Solution	New Solution	Update Solution
4709.57	5918.31	4709.57
4891.99	4970.88	4891.99
5751.66	5089.13	5089.13
4620	5352.64	4620
6437.1	5648.11	5648.11
5132.4	5269.12	5132.4
5384.5	4671.21	4671.21
6051.02	4749.41	4749.41
5619.4	5600.57	5600.57
5583.1	5456.22	5456.22

4.6. Production Scheduling Program

This scheduling program is based on Python, aiming to make it easier for companies to calculate existing scheduling. The front view of the production scheduling program can be seen in Figure 1 below.

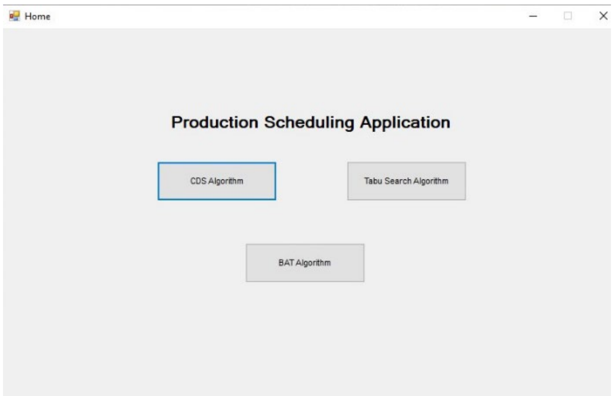

Figure 1. Program Front View

Next, here is a display of the CDS Algorithm, Bat Algorithm, and Tabu Search Algorithm, shown in Figure 2-4 below.

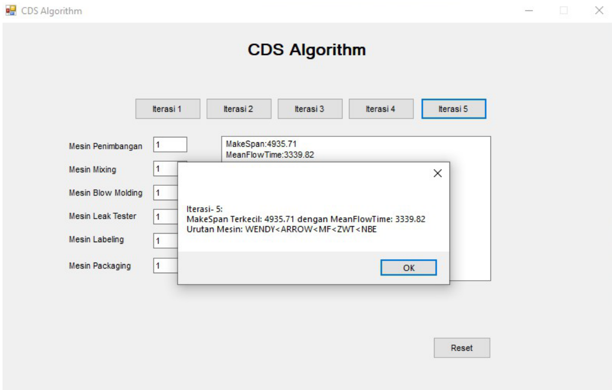

Figure 2. View of CDS Algorithm

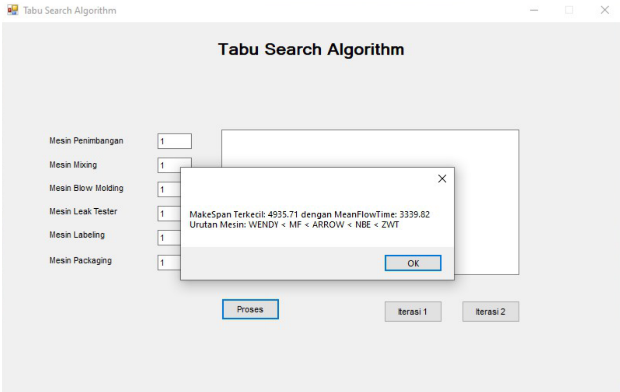

Figure 3. View of Bat Algorithm

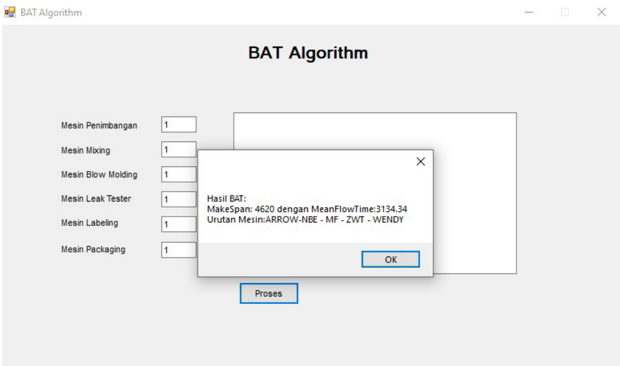

Figure 4. View of Tabu Search Algorithm

5. Conclusion

The conclusion of this research is the actual scheduling at PT. Dynaplast Jatake does not have a minimum makespan value, which is 4954.73 seconds. Tabu Search algorithm produces scheduling that can minimize makespan by 4935.72 seconds, which is smaller with the job order is Morning Fresh (MF) - Arrow - Wendy - ZWT – NB. Then, compared to the calculation, the CDS Algorithm is equal to 4935.72 seconds with the same job order as the Tabu Algorithm Search in the order of the job is Morning Fresh (MF) - Arrow - Wendy - ZWT - NBE. In the Bat Algorithm, the smallest makespan is 4620 seconds for the 4th bat in the order of the job is Arrow - NBE - Morning Fresh (MF) - ZWT - Wendy. However, the Bat Algorithm calculation can produce more optimal scheduling because it is very detailed and uses ten bats. There are 300 random values used for each position.

Based on manual calculations on the three algorithm methods above, the Bat Algorithm is the best solution for scheduling applications in production scheduling at PT. Dynaplast because it can produce the smallest makespan value.

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Biography

Maria Fatima Gracia Charista Elliani was born in Lampung, Indonesia on 19th May 1999. She graduated from a highly respected high school in Tangerang, Tarakanita Citra Raya. She is currently on her last year in Universitas Tarumanagara, majoring in Industrial Engineering. She used to be a member of the student executive council, Badan Eksekutif Mahasiswa Universitas Tarumanagara and has worked as an engineering laboratory assistant for two semester. In 2020, she had an internship in the Quality Control Division at PT. Straightway Primex and become Next Generation Professional (NGP) Mentees in Jakarta.

Lina Gozali is a lecturer at the Industrial Engineering Department of Universitas Tarumangara since 2006 and a freelance lecturer at Universitas Trisakti since 1995. She graduated with her Bachelor's degree at Trisakti University, Jakarta - Indonesia, then she got her Master's Degree at STIE IBII, Jakarta – Indonesia, and she recently got her Ph.D. at Universiti Teknologi Malaysia, Kuala Lumpur – Malaysia in 2018. Her apprentice college experience was in paper industry at Kertas Bekasi Teguh, shoes industry at PT Jaya Harapan Barutama, and automotive chain drive industry at Federal Superior Chain Manufacturing. She teaches Production System and Supply Chain Management Subjects. She did a research about Indonesian Business Incubator for her Ph.D. She has written almost 70 publications since 2008 in the Industrial Engineering research sector, such as Production Scheduling, Plant Layout, Maintenance, Line Balancing, Supply Chain Management, Production Planning, and Inventory Control. She had worked at PT. Astra Otoparts Tbk before she became a lecturer.

Frans Jusuf Daywin was born in Makasar, Indonesia on 24th November 1942. is a lecturer in the Department of Agricultural Engineering at Faculty of Agricultural Technology Bogor Agricultural University since 1964 conducted teaching, research, and extension work in the field of farm power and machinery and become a professor in Internal Combustion Engine and Farm Power directing and supervising undergraduate and graduate students thesis and dissertation and retired as a professor in 2007. In 1994 up to present as a professor in Internal Combustion Engine and Farm Power at Mechanical Engineering Program Study and Industrial Engineering Program Study Universitas Tarumanagara, directing and supervising undergraduate student's theses in Agricultural Engineering and Food Engineering Desain. In 2016 up to present teaching undergraduate courses of the introduction of concept technology, research methodology, and seminar, writing a scientific paper and scientific communication, and directing and supervising undergraduate student's theses in Industrial Engineering Program Study at the Faculty of Engineering Universitas Tarumanagara. He got his Ir degree in Agricultural Engineering, Bogor Agricultural University Indonesia in 1966, and finished the Master of Science in Agricultural Engineering at the University of Philippines, Los Banos, the Philippines 1981, and got the Doctor in Agricultural Engineering, Bogor Agricultural University Indonesia in 1991. He joined 4-month farm machinery training at ISEKI CO, AOTS, Japan in 1969 and 14 days agricultural engineering training at IRRI, Los Banos the Philippines, in March 1980. He received the honors "SATYA LANCANA KARYA SATYA XXX TAHUN" from the President of the Republic of Indonesia, April 22nd, 2006, and received appreciation as Team Jury from the Government of Indonesia Minister of Industry in Industry Start-Up 2008. He did several research and survey in the field of farm machinery, farm mechanization, agricultural engineering feasibility study in-field performance and cost analysis, land clearing and soil preparation in secondary forest and alang-alang field farm 1966 up to 1998. Up till now he is still doing research in designing food processing engineering in agriculture products. Up to the present he already elaborated as a conceptor of about

20 Indonesia National Standard (SNI) in the field of machinery and equipment. He joins the Professional Societies as a member: Indonesia Society of Agricultural Engineers (PERTETA); Indonesia Society of Engineers (PII); member of BKM-PII, and member of Majelis Penilai Insinyur Profesional BKM-PII.

Carla Olyvia Doaly is a lecturer in the Industrial Engineering Department at Universitas Tarumanagara graduated with my bachelor's degree from Institut Teknologi Nasional Malang, which study the Industrial Engineering program, then continued my Master Degree at Institut Teknologi Bandung majoring in Industrial engineering and management and a special field of Enterprise Engineering. I am very interested in studying industrial engineering by doing research related to System Design and Engineering, Supply Chain Management, Operations Research and Analysis, Information System Management, Occupational Health and Safety, Facilities Engineering, Quality and Reliability Engineering