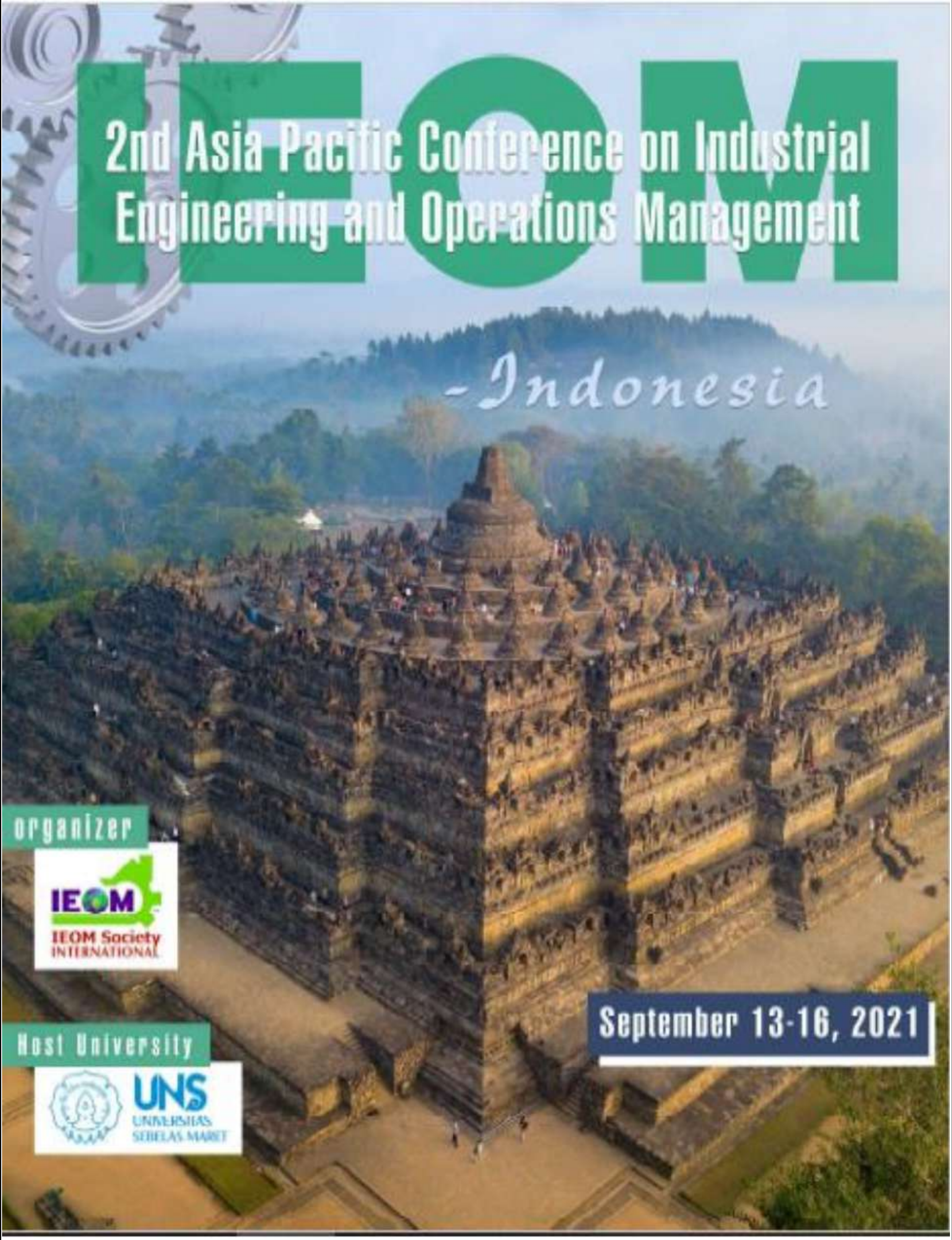
Flowshop Production Scheduling using CDS, Tabu Search, and Genetic Algorithm (Case Studies: CV. Mega Abadi)

by Lina Gozali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Conference Program

Day 1 – September 13 (Monday)

08:00 – 9:45 am Technical Presentations – Zoom Meeting Rooms 1-8
10:00 – 11:45 am Technical Presentations – Zoom Meeting Rooms 1-8
12:00 – 1:45 pm Technical Presentations – Zoom Meeting Rooms 1-8
02:00 – 3:45 pm Technical Presentations – Zoom Meeting Rooms 1-8
04:00 – 5:45 pm Technical Presentations – Zoom Meeting Rooms 1-8

Day 2 – September 14 (Tuesday)

8:00 am – Officially Opening the Conference from UNS Vice Rector – Zoom Meeting Room 1
8:20 am – Keynote Speaker I: **Dr. Jessika E. Trancik**, Professor, Institute for Data, Systems and Society (IDSS), Massachusetts Institute of Technology (Opening Keynote) – Zoom Meeting Room 1
9:00 am – Keynote Speaker II: **Dr. Jay Lee**, Vice Chairman and Board Member of Foxconn Technology Group, Member of World Economic Forum Global Future Council on Advanced Manufacturing and Production – Zoom Room 1
9:40 am – Keynote Speaker III: **Prof. George G. Q. Huang**, Chair Professor and Head, Department of Industrial and Manufacturing, Systems Engineering, The University of Hong Kong – Zoom Meeting Room 1
10:20 am Break
10:40 am – Keynote Speaker IV: **Dr. Robert de Souza**, The Executive Director of the The Logistics Institute – Asia Pacific (TLI – Asia Pacific), National University of Singapore, Singapore City, Singapore – Zoom Meeting Room 1
11:20 am Keynote Speaker V: **Harry Kasuma (Kiwi) Aliwarga**, CEO and Co-Owner, UMG Myanmar – Zoom Meeting Room 1

12:00 pm – LUNCH BREAK

1:00 pm – 2:45 pm – Technical Presentations – Zoom Meeting Rooms 1-8
2:45 pm – Break
3:00 pm – 4:45 pm – Technical Presentations – Zoom Meeting Rooms 1-8
4:45 pm – Break
5:00 pm – 6:45 pm Technical Presentations – Zoom Meeting Rooms 1-8

Day 3 – September 15 (Wednesday)

8:00 am – Conference Co-Chair Remarks – Zoom Meeting Rooms 1
8:20 am – Keynote Speaker VI: **Dr. Ahad Ali**, Associate Professor and Director of Industrial Engineering, Lawrence Technological University, Michigan, USA – Zoom Meeting Room 1
9:00 am – Keynote Speaker VII: **Prof. Dr. Eng. Koichi Murata**, College of Industrial Technology, Nihon University, Japan – Zoom Room 1
9:40 am – Keynote Speaker VIII: **Dr. Rajesh Piplani**, Associate Professor, The school of Mechanical and Aerospace Engineering, Systems and Engineering Management division, Nanyang Technological University, Singapore – Zoom Meeting Room 1
10:20 am Break
10:40 am – Keynote Speaker IX: **Dr. Ir. Bertha Maya Sopha**, Past Director of Industrial Engineering Undergraduate Program, Faculty of Engineering, Universitas Gadjah Mada (UGM), Yogyakarta, Indonesia and President – Indonesian Association of Industrial Engineering Higher Education Institution (BKSTI) – Zoom Meeting Room 1
11:20 am Keynote Speaker X: **Prof. Anicia Peters**, Pro-Vice Chancellor: Research, Innovation & Development, University of Namibia

12:00 pm – LUNCH BREAK

1:00 pm – 2:45 pm – Technical Presentations – Zoom Meeting Rooms 1-8
2:45 pm – Break
3:00 pm – 4:45 pm – Technical Presentations – Zoom Meeting Rooms 1-8
4:45 pm – Break
5:00 pm – 6:45 pm Technical Presentations – Zoom Meeting Rooms 1-8

Day 4 – September 16 (Thursday)

8:00 am – Conference Co-Chair Remarks – Zoom Meeting Rooms 1
8:20 am – Keynote Speaker XI: **Tom Gaasenbeek**, Founder and CEO, Nexas Networks Inc., Hamilton, Ontario, Canada – Zoom Meeting Room 1
9:00 am – Keynote Speaker XII: **Adil Dalal**, President & CEO, Pinnacle Process Solutions, Intl, Austin, Texas, USA – Zoom Meeting Rooms 1
9:40 am – Keynote Speaker XIII: **Dr. John Blakemore**, Adjunct Professor at University of Newcastle, Blakemore Consulting International, Sydney, Australia – Zoom Meeting Room 1
10:20 am Break
10:40 am – Keynote Speaker XIV: **Dr. Basuki Rahmad**, ST, MT, CEO, PT. Transforma Engineering & Solutions, Bandung, Java, Indonesia
11:20 am Keynote Speaker XV: **Dr. Zain Tahboub**, President, MENA College of Management (MCM), Dubai, UAE – Zoom Meeting Room 1

12:00 pm – LUNCH BREAK

1:00 pm – 2:45 pm – Technical Presentations – Zoom Meeting Rooms 1-8
2:45 pm – Break
3:00 pm – 4:45 pm – Technical Presentations – Zoom Meeting Rooms 1-8
4:45 pm – Break
5:00 pm – 6:45 pm Technical Presentations – Zoom Meeting Rooms 1-8

8:00 – 10:00 pm, September 16: Conference Awards Ceremony and Announcing Competition Winners

Rajasthan, INDIA

Digital twin in supply chain management

6:00 pm – 6:20 pm, Thursday, September 16

Engr. Numan Arshad
Certified PMP, RMP, ACP PMI-USA
Certified PSP-AACEI
Senior Training Consultant and Visiting Lecturer
Riphah International University
Islamabad, Pakistan

5:00 – 6:30 pm, THURSDAY — Operations Research — Room 2

Session Chair: Eric Wibisono, Department of Industrial Engineering, Faculty of Engineering, University of Surabaya, Surabaya, Indonesia

ID 006 Flowshop Production Scheduling Using Cds, Tabu Search And Genetic Algorithm (Case Studies: Cv. Mega Abadi)
Lina Gozali, Vania Eliyanti, Lamto Widodo, and Frans Jusuf Daywin, Industrial Engineering, Universitas Tarumanagara, Indonesia
Agustinus Purna Irawan, Mechanical Engineering, Universitas Tarumanagara, Indonesia
Harto Tanujaya, Industrial Engineering, Universitas Tarumanagara, Indonesia
Siti Rohana Nasution, Industrial Engineering, UPN Veteran, Jakarta, Indonesia

ID 099 Simulated Annealing Algorithm for Vehicle Routing Problem with Simultaneous Pick Up and Delivery: A Case Study of Liquid Petroleum Gas Distribution
Fatikhatuz Zahra, Prima Arinda Nurul Islami and Nur Layli Rachmawati, Department of Logistics Engineering, Universitas Pertamina, DKI Jakarta, 12220, Indonesia
A.A.N. Perwira Redi, Department of Industrial Engineering, BINUS Graduate Program – Master of Industrial Engineering, Universitas Bina Nusantara, DKI Jakarta, 11480, Indonesia
Reny Nadlifatin, Department of Information System, Institut Teknologi Sepuluh, Nopember, Surabaya, 60111, Indonesia
Agus Supranartha, Department of Electrical Engineering, Universitas Pendidikan Nasional, Bali, Indonesia

ID 113 Modification of Non-delay Algorithm to Minimize Makespan
Nur Ezha Vidawati, Management Trainee Supply Chain, PT. Nestle, Indonesia
Puryani and Apriani Soepardi, Department of Industrial Engineering, Faculty of Industrial Engineering, Universitas Pembangunan Nasional Veteran, Yogyakarta, Indonesia

ID 284 Effect of Social Support on Elderly Welfare Using Structural Equation Modelling (SEM)
Restu Aji Nur Kahfi BP, Industrial Engineering Postgraduate Program, Universitas Islam Indonesia, Yogyakarta, Indonesia
Hari Purnomo, Industrial Engineering Program, Universitas Islam Indonesia, Yogyakarta, Indonesia
Ayudyah Eka Apsari, Industrial Engineering Program, Universitas Islam Batik Surakarta, Surakarta, Indonesia

ID 702 Heuristic Algorithm to Minimize Maximum Lateness for Job-shop Scheduling Problem in Automotive Industry
Docki Saraswati, Debbie Kemala Sari and Nesya Dwi Permata, Department of Industrial Engineering, Universitas Trisakti, Jakarta, Indonesia

ID 274 Comparison of crossover operators in genetic algorithm for vehicle routing problems
Eric Wibisono, Iris Martin, and Dina Natalia Prayogo, Department of Industrial Engineering, Faculty of Engineering, University of Surabaya, Surabaya, Indonesia

5:00 – 6:30 pm, THURSDAY — Modeling and Simulation — Room 3

Session Chair: Muhammad Nadzmi Muhammad Idlan, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia

ID 078 Sales Prediction of Multi-Item Time Series Using Autoregresive Integrated Moving Average and Long Short-Term Memory on Perishable Products
Abdullah 'Azzam, Shelly Elvina Salsabila, Suci Miranda, Department of Industrial Engineering, Islamic University of Indonesia, Kaliurang Street KM 14,5 Yogyakarta

ID 417 Age-Dependent Inventory Routing Problem Model for Medical Waste Collection
Ridho Syahrial Ibrahim, and Ahmad Rusdiansyah, Department of Industrial and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

ID 697 Techno-Economic Feasibility Analysis of Agricultural Drone Business in Indonesia
Nida An Khofiyah, Master Program of Industrial Engineering Department, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia
Muhammad Hisjam, University Centre of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret, Surakarta, Indonesia
Wahyudi Sutopo, Research Group Industrial Engineering and Techno-Economic, Department of Industrial Engineering, Faculty of Engineering Universitas Sebelas Maret, Surakarta, Jl. Ir. Sutami, 36 A, Surakarta, Indonesia

ID 416 Eveloped SERVQUAL Model in Measuring Customer Satisfaction for Ferry Service in Langkawi
Muhammad Nadzmi Muhammad Idlan, Graduate Research Assistant, Malaysia Institute of Transport (MITRANS), Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia
Harlina Suzana Jaafar, Associate Professor, Department of Technology and Supply Chain Management, Faculty of Business and Management Universiti Teknologi Mara, Selangor Branch, Puncak Alam Campus, 42300 Bandar Puncak Alam, Selangor, Malaysia

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Lina Gozali, ST.,MM.,Ph.D
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Southfield, Michigan, USA

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Flowshop Production Scheduling using CDS, Tabu Search, and Genetic Algorithm (Case Studies: CV. Mega Abadi)

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Abstract

CV. Mega Abadi is a company in the manufacturing industry that produces paints. One of the superior products is epoxy paint. In fulfilling the customer's needs, the company is used to make to stock strategy, where the products that have been produced will be stored, and the customer's needs will be taken from the warehouse. The production pattern in this company is flowshop, where the jobs have the same production sequence. The marketing department has done the production schedule based on the product demand forecast, and then it will be sorted from the highest to the lowest demand forecast. The purpose of this research is to give a machine scheduling design to minimize makespan. The heuristic method used is Campbell, Dudek, and Smith (CDS) Algorithm, and the meta-heuristic methods used to obtain the most optimal result are Tabu Search Algorithm and Genetic Algorithm. After calculating the company's actual scheduling that begins with the forecast of the production amount with the decomposition method, its scheduling sequence is obtained. It can be known that the company's makespan is 334,68 minutes and flowtime 286,53 minutes. The results of data processing show that Tabu Search Algorithm produces the most optimal value with the production sequence 6018 Epoxy TC Yellow Green - 7001 Epoxy TC Light Grey - 1003 Epoxy TC Banana Yellow -9017 Epoxy TC Black - 9016 Epoxy TC Snow White with makespan 313,13 minutes and flowtime 288,61 minutes, and the result for the efficiency index is 1,068 and 7,61% of relative error. This research aims to create a production scheduling application/software that can help arrange the production schedule.

Keywords
Production Scheduling, Flowshop, Campbell Dudek and Smith (CDS) Algorithm, Tabu Search Algorithm, Genetic Algorithm, Decomposition Forecasting

1. Introduction

Scheduling is one of the most critical things in the manufacturing system. Scheduling can be determined as allocating resources or existing machines to carry out a set of tasks within a certain period of time [Baker, 1974]. In general, production scheduling allocates available resources and machinery to complete all work with certain considerations, including minimizing the time completion (makespan) and meeting the due date.

Incorrect job sequences can lead to high total production time. It can also cause the number of products produced not to meet the target or customer demand, increase production costs and overtime costs, etc. Therefore, companies need to determine the proper and adequate production scheduling.

CV. Mega Abadi is a manufacturing industry that produces paint. The products such as Duco paint, alkyd paint, wall paint, and epoxy paint. The superior product namely epoxy paint. Epoxy paint is floor paint that consists of a combination of epoxy polymers and hardeners. In the production process activities, CV. Mega Abadi used some tools and machines, both semi-automatic and automatic, such as weighers, small mixers, large mixers, press tools, etc. To meet customer demand, the company uses a make to stock strategy, where products produced will be stored, and the customer will be taken from inventory at the warehouse. The production pattern in this company is flowshop, where every job has the same production sequence.

Currently, the production scheduling from CV. Mega Abadi is done manually by the marketing department based on product demand forecasting, sorted from the highest to the lowest forecasting. In production activities, the employees often prioritize several jobs based on personal considerations. Difficulties often occur, especially when demand outside production increases. Production scheduling is currently unable to meet the number of products to meet the production targets. This problem indicates that scheduling at the company is not good. Based on the description above, it is necessary to determine the most optimal production sequence in companies with flowshop production floors to minimize the makespan using heuristic and meta-heuristic scheduling methods. The heuristic method used as an initial solution is Campbell, Dudek, and Smith (CDS) Algorithm. The meta-heuristic method used to obtain the most optimal results or solutions is Tabu Search Algorithm and Genetic Algorithm.

2. Literature Review

2.1 Production Scheduling

Baker (1974) defines scheduling as allocating existing sources or machines to carry out a set of tasks within a certain period of time. Meanwhile, according to Vollman (1997), scheduling is a work order arrangement plan and resource allocation, both time and facilities for each operation that must be completed (Kom, 2016). From this understanding, Baker and Vollman explain that scheduling is the process of managing sources or machines to complete a task or operation within a certain period of time. Good production scheduling can reduce the idle time (idle time) on production units and optimize goods in the process (work in process).

2.2 Flowshop Scheduling

Flow shop scheduling system is the scheduling of all jobs with the same process sequence, and each job goes to each machine at a certain time and is only processed once by each type of machine. Each job is processed sequentially, i.e., moving from one machine to the next. The flowshop's flow is divided into four categories: pure flow shop, where each job flows on the same production line, through all machines, and each job has one operation on each machine. General flow shop, where a job can consist of less than m operations, does not always start on the first machine or end on the last machine. Reentrant flow shop, where several machines can be passed more than once. Hybrid flow shop, where one machine in a machine set can be replaced by a group of machines (Morton & Pentico, 1993).

2.3 Campbell, Dudek, and Smith (CDS) Algorithm

CDS is a production scheduling method that can minimize makespan and gives near-optimal solutions (Ginting, 2009). The steps for scheduling with the CDS algorithm are:

a. Determine the number of iterations, i.e., the number of machines - 1.
b. Take the first scheduling (K = 1). For all jobs, look for the minimum value of t * i, 2, which is the processing time on the first and second machines, where t * i, 1 = ti, 1 and t * i, 2 = ti, 2. Do it also for the next iteration.
c. Do Johnson's rules. If the minimum time is obtained on the first machine (e.g., ti, 1), place the task at the beginning of the scheduling sequence. If the minimum time is obtained on the second machine (e.g., ti, 2), the task is placed in the scheduling sequence's final position.
d. Remove these tasks from the list and arrange them in a scheduling sequence. If there are still jobs left, that means scheduling is complete.

2.4 Tabu Search Algorithm

Tabu Search is an optimization method based on local search. Tabu Search is a meta-heuristic method used to look for other possible solutions near-optimal (Glover, F. and M. Laguna, 1991). The search process moves from one solution to the next. The trick is to choose the best neighbourhood solution now that it is not classified as a forbidden solution (taboo). The steps in the taboo search method, such as: determining the initial solution using the heuristic method; determining the number of iteration calculations; calculating the value of an objective function with a neighbourhood switch; selecting the best objective function if the objective function is the same as the initial solution, then choose the other best objective function, if the values of the two objective functions are the same, select one candidate; the newest candidate is used as the initial solution for the next iteration. Repeat some iterations that have been determined (Pinedo and Chao, 1999).

2.5 Genetic Algorithm

The genetic algorithm first introduced by Holland and De Jong in 1975 is a stochastic optimum value search technique based on the theory of evolution's basic principles. Genetic Algorithms can refer to all methods of finding neighbour solutions by simulating the process of natural evolution. The Genetic Algorithm method's scheduling procedure is as follows: initial population initialization; individual coding; determination of objective functions; determination of fitness value; selection; cross move or crossover; mutation (Alfandianto, Nugroho, & Setiafindari, 2017).

2.6 Decomposition Forecasting

The decomposition forecasting method is to identify three components or factors in a data series, such as the trend, seasonal, and cycle components. The decomposition method is used to predict periodic series of data that shows trends and seasonal influences. Illustrated as follows:

Data = Pattern + error……………………………………………………………………………………(3)
Or mathematically, this equation can be written as follows:
$X_t = f(S_t, T_t, C_t, R_t)$……………………………………………………………………………………(4)
Information:
S_t is a component of the trend in period t
T_t is the seasonal component (index) in period t
C_t is the cycle component in period t
R_t is the random component (error) in period t

3. Methods

The research methodology is a basic principle in researching to be more coordinated, directed, and smooth. The research methodology contains the stages in research, which can be seen in Figure 1.

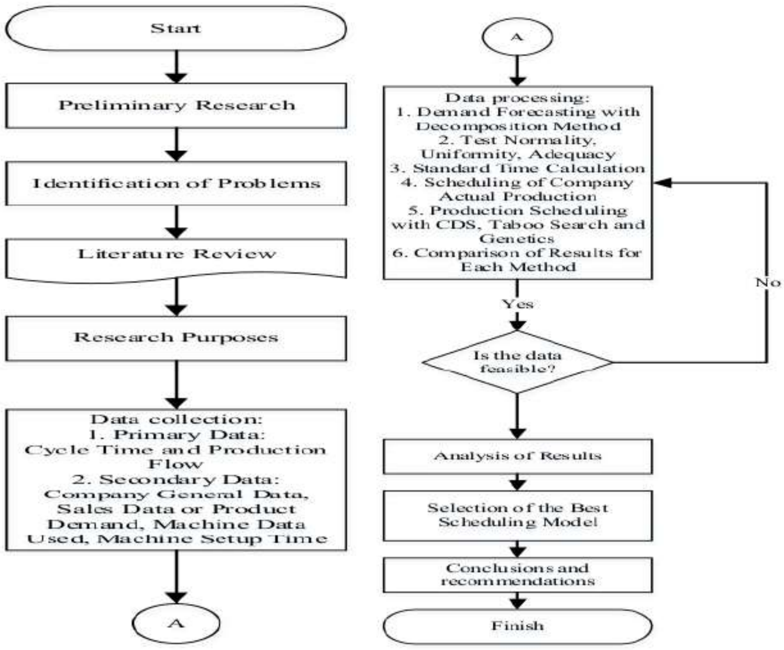

Figure 1. Flow Chart Research Methodology

4. Data Collection

4.1 Machine Data

The machines used for the production process are automatic and semi-automatic machines. Machine data can be seen in Table 1 below.

Table 1. Production Machine Data

Process	Machine Name	Capacity (l)	Number of Machines (unit)	Set-Up Time/Process (minutes)
Weighing	Scale	-	1	0,5
Pre-mixing	Small Mixer	200	3	1,5
Mixing / Grinding	Large Mixer	300	3	1,5
Filtering / Screening	Filter Machine	200	4	0,5
Quality Test	Color and Fineness Test Equipment	-	4	0,5
Packing	Press Tool	-	5	0,5

4.2 Product Demand Data

The request data will be a scheduled job—product demand data in the CV. Mega Abadi is made in a monthly period. The following is the demand for epoxy paint in January - August 2019 with 20-litre cans, as shown in Table 2 below.

Table 2. Product Demand Data (unit cans)

Period	Product				
	6018 *Epoxy* TC *Yellow Green*	1003 *Epoxy* TC *Banana Yellow*	9016 *Epoxy* TC *Snow White*	7001 *Epoxy* TC *Light Grey*	9017 *Epoxy* TC *Black*
January	59	45	60	55	45
February	58	42	59	62	48
March	60	42	60	60	45
April	59	45	56	55	42
May	50	52	56	50	50
June	49	52	55	55	55
Jule	55	50	55	55	50
August	50	55	50	50	48

4.3 Processing Time Data

It is essential to obtain the processing time; the cycle time is calculated using the stop-clock method (Liesly, Gozali, & Jap, L, 2019). After that, normal time and standard time are calculated (Gozali & Aditya, 2013). The processing time is obtained from the standard time, which is added to the setup time. Processing time data can be seen in Table 3 below.

Table 3. Processing Time Data (minutes)

Job		*Pre-Mixing*	*Mixing*	*Filtering*	Uji Kualitas	*Packing*
6018	20,72	66,65	64,79	49,39	25,18	28,61
1003	21,27	68,33	65,62	50,97	26,22	28,44
9016	18,09	55,80	52,27	46,85	25,02	28,45
7001	19,22	60,03	57,29	49,94	27,69	29,06
9017	20,76	62,28	56,17	49,35	24,94	30,51

4.4 Decomposition Forecasting

Forecasting determined the number of products produced in September, using preliminary data from January to August 2019. After forecasting the production amount to determine the order of company scheduling by the decomposition method, the results can be seen in Table 4 below.

Table 4. Decomposition Forecasting Results

Product	Total (unit cans)
6018 *Epoxy* TC *Yellow Green*	42
1003 *Epoxy* TC *Banana Yellow*	61
9016 *Epoxy* TC *Snow White*	51
7001 *Epoxy* TC *Light Grey*	46
9017 *Epoxy* TC *Black*	56

4.5 Company's Actual Scheduling

The company's actual scheduling is obtained from sorting forecasting from the largest to the smallest, so that the actual scheduling is obtained, namely 1003 Epoxy TC Banana Yellow - 9017 Epoxy TC Black - 9016 Epoxy TC Snow White - 7001 Epoxy TC Light Gray - 6018 Epoxy TC Yellow Green, with makespan 338.93 minutes and flowtime 290.55 minutes.

4.6 Scheduling with Campbell, Dudek, and Smith (CDS) Algorithm

Scheduling with the CDS algorithm begins by determining the number of iterations or K values with the formula m-1, where m is the number of machines or stages. The CV. Mega Abadi has 6 stages or stages, so 5 iterations must be completed. The table of makespan and flowtime values for each iteration can be seen in Table 5 below.

Table 5. Makespan and Flowtime Value Tables

Iteration	*Makespan* (minutes)	*Flowtime* (minutes)
K1	337,96	284,09
K2	316,59	286,98
K3	327,03	290,28
K4	326,02	292,98
K5	338,49	282,44

Based on the CDS method calculations, the most optimal job sequence was obtained in the second iteration with makespan 316.59 minutes and flowtime 286.98 minutes.

4.7 Scheduling with Tabu Search Algorithm

Tabu Search Algorithm is a continuation of the initial solution that has been obtained with the CDS Algorithm (Gozali,, Halim & Jap, 2019). Tabu Search Algorithm is a meta-heuristic method used to obtain a more optimal makespan and job order. First, to determine the aspiration level obtained from scheduling, the heuristic method with Z best derived from scheduling with the CDS algorithm (Gozali, Ariyanti & Tanujaya (2014)). Next, that is creating a taboo list and candidate list. There will be a job exchange (Pn to Px switch) and the results of the job exchange on the candidate list. The taboo list can be seen in Table 6 below.

Tabel 6. Tabu List

	Time (minutes)			
	Iteration 0	Iteration 1	Iteration 2	Iteration 3
Makespan	316,59	316,14	313,13	316,14
Mean Flow Time	286,98	290,21	288,61	290,21

The taboo list column that has been filled shows that the stopping criteria have been reached. The scheduling results with the best Tabu Search Algorithm, namely 6018 Yellow Green - 7001 Light Gray - 1003 Banana Yellow -9017 Black - 9016 Snow White with makespan 313.13 minutes and flowtime 288.61 minutes.

4.8 Scheduling with Genetic Algorithms

The steps in scheduling with Genetic Algorithms, such as:

1. Determination of the parameters us
   The parameters used in this study (popsize; pc; pm) = (30; 0.95; 0.01), where each generation's average fitness is used as an indicator.
2. Populatio nitialization Each product is made a notation to make it easier to randomize the job sequence. Product notation can be seen in Table 7 below.

Table 7. Product Notation

Product	Notation
7001 *Light Grey*	A
9017 *Black*	B
1003 *Banana Yellow*	C
6018 *Yellow Green*	D
9016 *Snow White*	E

After the initialization stage is done, the randomization action carried out in a coordinated manner so that the selected chromosomes are obtained as much as pop size. The selected chromosomes can be seen in Table 8 below.

Table 8. Selected Chromosomes

Chromosome	Chromosome order	Chromosome	Chromosome order	Chromosome	Chromosome order
I1	ABCDE	I11	AEDCB	I21	BDCAE
I2	BACDE	I12	AEDBC	I22	BCDAE
I3	BCADE	I13	EADBC	I23	CBDAE
I4	BCAED	I14	EDABC	I24	CDBAE
I5	CBAED	I15	EDBAC	I25	CDBEA
I6	CABED	I16	EDBCA	I26	DCBEA
I7	CAEBD	I17	DEBCA	I27	DCBAE
I8	CAEDB	I18	DBECA	I28	ECBAD
I9	ACEDB	I19	DBCEA	I29	CEBAD
I10	AECDB	I20	DBCAE	I30	CBEAD

3. Evaluation
Done by counting the makespan and fitness value of each chromosome. The formula obtains the fitness value:

$$\text{Fitness} = \frac{1}{Ms} \qquad (5)$$

The results of the calculation of each chromosome's makespan and fitness values can be seen in Table 9 below.

Table 9. Makespan and Initial Population Fitness Value

Chromosome	Chromosome order	*Makespan* (minutes)	*Fitness*
I1	ABCDE	316,59	0,00316
I2	BACDE	317,66	0,00315
I3	BCADE	328,57	0,00304
I4	BCAED	344,98	0,00290
I5	CBAED	338,93	0,00295
I6	CABED	335,14	0,00298
I7	CAEBD	335,14	0,00298
I8	CAEDB	324,22	0,00308
I9	ACEDB	335,41	0,00298
I10	AECDB	323,31	0,00309
I11	AEDCB	323,31	0,00309
I12	AEDBC	339,64	0,00294
I13	EADBC	339,64	0,00294
I14	EDABC	345,04	0,00290
I15	EDBAC	345,04	0,00290
I16	EDBCA	334,23	0,00299
I17	DEBCA	326,95	0,00306
I18	DBECA	327,77	0,00305
I19	DBCEA	327,77	0,00305
I20	DBCAE	316,14	0,00316
I21	BDCAE	325,51	0,00307
I22	BCDAE	328,57	0,00304
I23	CBDAE	317,20	0,00315
I24	CDBAE	326,02	0,00307
I25	CDBEA	337,41	0,00296
I26	DCBEA	339,92	0,00294
I27	DCBAE	328,53	0,00304
I28	ECBAD	342,31	0,00292
I29	CEBAD	334,68	0,00299
I30	CBEAD	338,93	0,00295
Total *Fitness*			0,09056

4. First Generation Calculations
   a. Chromosome selection by the Roulette Wheel Method
   First, that is to do the calculation of relative fitness (pi) with the formula:

$$\text{pi} = \frac{fitness\ value\ Ii}{total\ fitness} \qquad (6)$$

   Then, proceed with the calculation of the cumulative fitness value (qi) with the formula:

$$\text{qi} = \text{pi} \qquad (7)$$

$$\text{q2} = \text{q1} + \text{p2} \qquad (8)$$

The relative fitness and cumulative fitness values of generation 1 chromosomes can be seen in Table 10 below.

Table 10. Relative Fitness and Cumulative Fitness of Generation 1 Chromosomes

Chromosome	Relative Fitness (Pi)	Cumulative Fitness (Qi)	Chromosome	Relative Fitness (Pi)	Cumulative Fitness (Qi)	Chromosome	Relative Fitness (Pi)	Cumulative Fitness (Qi)
I1	0,0349	0,0349	I11	0,0342	0,3690	I21	0,0339	0,7011
I2	0,0348	0,0696	I12	0,0325	0,4015	I22	0,0336	0,7347
I3	0,0336	0,1032	I13	0,0325	0,4340	I23	0,0348	0,7695
I4	0,0320	0,1353	I14	0,0320	0,4660	I24	0,0339	0,8034
I5	0,0326	0,1678	I15	0,0320	0,4980	I25	0,0327	0,8361
I6	0,0329	0,2008	I16	0,0330	0,5311	I26	0,0325	0,8686
I7	0,0329	0,2337	I17	0,0338	0,5648	I27	0,0336	0,9022
I8	0,0341	0,2678	I18	0,0337	0,5985	I28	0,0323	0,9344
I9	0,0329	0,3007	I19	0,0337	0,6322	I29	0,0330	0,9674
I10	0,0342	0,3349	I20	0,0349	0,6671	I30	0,0326	1

Generate as many random numbers as pop size, 30 on Microsoft. Excel with the formula RAND (). After that, selection can be made by sorting chromosomes according to the cumulative fitness value of each chromosome against random numbers. If the random number <fitness is cumulative, then select the chromosome as the parent candidate. The chromosomes selected are marked with a sign ('), as shown in Table 11 below.

Table 11. New Chromosomes Selected Results

Chromosome	Sequence	Makespan (minutes)	Fitness Value	Original Chromosome
I'1	BDCAE	325,51	0,003072102	I21
I'2	ABCDE	316,59	0,003158659	I1
I'3	CDBAE	326,02	0,003067296	I24
I'4	CAEDB	324,22	0,003084325	I8
I'5	DEBCA	326,95	0,003058572	I17
I'6	EDABC	345,04	0,002898215	I14
I'7	EADBC	339,64	0,002944294	I13
I'8	BCDAE	328,57	0,003043491	I22
I'9	AEDCB	323,31	0,003093007	I11
I'10	CBDAE	317,2	0,003152585	I23
I'11	ACEDB	335,41	0,002981426	I9
I'12	DCBEA	339,92	0,002941869	I26
I'13	CEBAD	334,68	0,002987929	I29
I'14	EDBAC	345,04	0,002898215	I15
I'15	AEDBC	339,64	0,002944294	I12
I'16	EDBCA	334,23	0,002991952	I16
I'17	CBAED	338,93	0,002950462	I5
I'18	BCAED	344,98	0,002898719	I4
I'19	DBECA	327,77	0,00305092	I18
I'20	AECDB	323,31	0,003093007	I10

Chromosome	Sequence	Makespan (minutes)	Fitness Value	Original Chromosome
I'21	CDBEA	337,41	0,002963753	I25
I'22	DCBAE	328,53	0,003043862	I27
I'23	ECBAD	342,31	0,002921329	I28
I'24	CBEAD	338,93	0,002950462	I30
I'25	DBCAE	316,14	0,003163156	I20
I'26	DBCEA	327,77	0,00305092	I19
I'27	CABED	335,14	0,002983828	I6
I'28	BCADE	328,57	0,003043491	I3
I'29	CAEBD	335,14	0,002983828	I7
I'30	BACDE	317,66	0,00314802	I2

The next step is a crossover. Crossovers can be initiated by generating random numbers. After generating random numbers with the formula RAND () on Microsoft. Excel. Choose a random number that is smaller than a pc or crossover opportunity. Chromosomes that experience crossovers can be seen in Table 12 below.

Table 12. Chromosomes that Have Crossovers

Chromosome	Sequence	Makespan (minutes)	Fitness Value
I'1	BDCAE	325,51	0,003072102
I'2	ABCDE	316,59	0,003158659
I'3	CDBAE	326,02	0,003067296
I'4	CAEDB	324,22	0,003084325
I'5	DEBCA	326,95	0,003058572
I'6	EDABC	345,04	0,002898215
I'7	EADBC	339,64	0,002944294
I'8	BCDAE	328,57	0,003043491
I'9	AEDCB	323,31	0,003093007
I'10	CBDAE	317,2	0,003152585
I'11	ACEDB	335,41	0,002981426
I'12	DCBEA	339,92	0,002941869
I'13	CEBAD	334,68	0,002987929
I'15	AEDBC	339,64	0,002944294
I'16	EDBCA	334,23	0,002991952
I'17	CBAED	338,93	0,002950462
I'18	BCAED	344,98	0,002898719
I'19	DBECA	327,77	0,00305092
I'20	AECDB	323,31	0,003093007
I'21	CDBEA	337,41	0,002963753
I'22	DCBAE	328,53	0,003043862
I'23	ECBAD	342,31	0,002921329

I'25	DBCAE	316,14	0,003163156
I'26	DBCEA	327,77	0,00305092
I'28	BCADE	328,57	0,003043491
I'29	CAEBD	335,14	0,002983828
I'30	BACDE	317,66	0,00314802

The selected chromosomes can be crossover. The method used is Two Point Crossover. The results of crossovers of all chromosomes can be seen in Table 13.

Table 13 Results of Generation I Crossovers

Chromosome	Sequence	Makespan (minutes)	Chromosome	Sequence	Makespan (minutes)	Chromosome	Sequence	Makespan (minutes)
I"1	ABCDE	316,59	I"10	CEDBA	324,07	I"20	CDBAE	326,02
I"2	DBCAE	316,14	I"11	ACBED	343,44	I"21	AECDB	323,31
I"3	CDBAE	326,02	I"12	DCEBA	339,92	I"22	ECDBA	337,29
I"4	CAEDB	324,22	I"13	AECBD	334,68	I"23	DCEBA	339,92
I"5	EDABC	345,04	I"15	CEADB	324,22	I"25	DBCEA	327,77
I"6	DEBAC	339,64	I"16	DBAEC	343,34	I"26	DBCAE	316,14
I"7	BCDEA	339,96	I"17	ADBCE	323,97	I"28	BAECD	334,68
I"8	EADBC	339,64	I"18	DBECA	327,77	I"29	ECABD	342,31
I"9	ABDEC	341,84	I"19	CBAED	338,93	I"30	DBCAE	316,14

The results of the crossover are then carried out mutations, with the steps:
a. Count the number of bits in the population, i.e. pop size x L = 30 x 5 = 150. L is the number of job sequences.
b. Generating as many as 150 random numbers.
c. Choose a random number whose value is below the chance of a mutation (pm) of 0.01. The mutation results can be seen in Table 14 below.

Tabel 14. The result from mutation

Chromosome	Mutated Job	Job Sequence	Makespan (minute)
I*6	1	CBDEA	328,32
I*8	3	ACDBE	327,03

The final population of the first generation can be seen in the following Table 15.

Table 15. Final First Generation and Early Second-Generation Populations

Chromosome	Sequence	Makespan (minutes)	Fitness Value	Chromosome	Sequence	Makespan (minutes)	Fitness Value
I"1	ABCDE	316,59	0,003158659	I"16	DBAEC	343,34	0,002912565
I"2	DBCAE	316,14	0,003163156	I"17	ADBCE	323,97	0,003086706
I"3	CDBAE	326,02	0,003067296	I"18	DBECA	327,77	0,00305092
I"4	CAEDB	324,22	0,003084325	I"19	CBAED	338,93	0,002950462
I"5	EDABC	345,04	0,002898215	I"20	CDBAE	326,02	0,003067296
I*6	CBDEA	328,32	0,003045809	I"21	AECDB	323,31	0,003093007

Chromosome	Sequence	Makespan (minutes)	Fitness Value	Chromosome	Sequence	Makespan (minutes)	Fitness Value
I"7	BCDEA	339,96	0,002941523	I"22	ECDBA	337,29	0,002964808
I*8	ACDBE	327,03	0,003057823	I"23	DCEBA	339,92	0,002941869
I"9	ABDEC	341,84	0,002925345	I'24	CBEAD	338,93	0,002950462
I"10	CEDBA	324,07	0,003085753	I"25	DBCEA	327,77	0,00305092
I"11	ACBED	343,44	0,002911717	I"26	DBCAE	316,14	0,003163156
I"12	DCEBA	339,92	0,002941869	I'27	CABED	335,14	0,002983828
I"13	AECBD	334,68	0,002987929	I"28	BAECD	334,68	0,002987929
I'14	EDBAC	345,04	0,002898215	I"29	ECABD	342,31	0,002921329
I"15	CEADB	324,22	0,003084325	I"30	DBCAE	316,14	0,003163156

The selected results are I"26 with makespan 316.14 minutes and flowtime 290.21 minutes in the first generation. Then, continue to the second generation with the initial population using the first generation's final population. Recapitulation of the results to show each generation's best chromosomes can be seen in Table 16 below.

Table 16. Recapitulation of Chromosome Results

Generation	Chromosome Sequence	Makespan (minutes)	Flowtime	Fitness Value
I	DBCAE	316,14	290,21	0,00316316
II	DBCAE	316,14	290,21	0,00316316

The calculation stops until generation 2 because the value of fitness no longer changes in the second generation, which is 0.00316316. Then, the iteration stops, and the chosen job sequence is DBCAE or 6018 Yellow Green - 9017 Black - 1003 Banana Yellow - 7001 Light Gray - 9016 Snow White with makespan 316.14 and flowtime 290.21 minutes.

5. Results and Discussion

The following compares the company's actual scheduling with production scheduling design, shown in Table17.

Tabel 17. The Comparison of Each Production Scheduling Method

	Actual	CDS Algorithm	Tabu Search Algorithm	Genetic Algorithm
Job Sequence	1003 *Epoxy* TC *Banana Yellow* - 9017 *Epoxy* TC *Black* - 9016 *Epoxy* TC *Snow White* - 7001 *Epoxy* TC *Light Grey* - 6018 *Epoxy* TC *Yellow Green*	7001 *Epoxy* TC *Light Grey* – 1003 *Epoxy* TC *Banana Yellow* – 9017 *Epoxy* TC *Black* – 6018 *Epoxy* TC *Yellow Green* – 9016 *Epoxy* TC *Snow White*	6018 *Epoxy* TC *Yellow Green* - 7001 *Epoxy* TC *Light Grey* - 1003 *Epoxy* TC *Banana Yellow* -9017 *Epoxy* TC *Black* - 9016 *Epoxy* TC *Snow White*	6018 *Epoxy* TC *Yellow Green* – 9017 *Epoxy* TC *Black* – 1003 *Epoxy* TC *Banana Yellow* – 7001 *Epoxy* TC *Light Grey* – 9016 *Epoxy* TC *Snow White*
Makespan	338,93	316,59	313,13	316,14
Mean Flowtime	290,55	286,98	288,61	290,21
Efficiency Index	-	1,057	1,068	1,06
Relative Error	-	6,59%	7,61%	6,72%

Based on the above comparison, it can be seen that the Tabu Search Algorithm produces the minimum makespan when compared with the company's actual methods and other methods. The following compares the best results

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from manual calculations with a program designed, a simple Python-based application program, which can be seen in Table 18 below.

Table 18. Comparison The Results of Manual and Program Calculations

	Manual Calculation		Program Calculation	
	Makespan	Mean Flowtime	Makespan	Mean Flowtime
CDS Algorithm	316,59	286,98	316,59	287,04
Tabu Search Algorithm	313,13	288,61	313,13	289,6
Genetic Algorithm	316,14	290,21	316,19	282,83

Based on Table 18, there isn't much difference between manual calculations and program calculations. Therefore, it can be concluded that the results of the designed program are valid.

6. Conclusions

Based on the results of manual calculations, Tabu Search Algorithm produces scheduling that minimizes the makespan of 313.13 minutes and the mean flow time of 288.61 minutes, with an efficiency index of 1.068 and a relative error of 7.61%. Genetic Algorithms can produce more optimal scheduling based on calculations using the program because the program can be calculated for up to 500 generations. Thus, Genetic Algorithms are the best to be used as scheduling.

References

Baker, K. R. (1974). *Introduction to sequencing and scheduling*. John Wiley & Sons.

Kom, E. D. M. (2016). Performance Algoritma Genetika (GA) Pada Penjadwalan Mata Pelajaran. *InfoTekJar: Jurnal Nasional Informatika dan Teknologi Jaringan*, *1*(1), 56-60.

Morton, T., & Pentico, D. W. (1993). *Heuristic scheduling systems: with applications to production systems and project management* (Vol. 3). John Wiley & Sons.

Ginting, R. (2009). Penjadwalan Mesin. *Yogyakarta: Graha Ilmu.*

Glover, F. & M. Laguna. Target Analysis to Improve a Tabu Search Method for Machine Schedulling. The Arabian Journal for Science and Engineering Vol. 16. No. 2B (1991): 239-253

Pinedo, Michael & X. Chao. *Operations Scheduling with Applications in Manufacturing and Service*. Singapore: Mc.Graw-Hill, 1999

Alfandianto, A., Nugroho, Y. A., & Setiafindari, W. (2017). "Penjadwalan Produksi Menggunakan Pendekatan Algoritma Genetika di PT. Pertani (Persero) Cabang di Yogyakarta". *Jurnal DISPROTEK*, *8*(2)

Liesly, L., Gozali, L., & Jap, L. (2019). The Design of Hybrid Flow Shop Scheduling System with Tabu Search (TS) Method to Minimize Makespan at PT. Plasindo Elok.

Gozali, L., & Aditya, V. (2013). Usulan Penjadwalan Flowshop dengan Pendekatan Algoritma Tabu Search dan Algoritma Genetika di PT. Super Metal Bangka Jaya. *Jurnal Ilmiah Teknik Industri*, *1*(2).

Gozali, Lina & Halim, Meisya & Jap, Lilyana. (2019). Analysis of Designing Job Shop Scheduling at PT. Harmoni Empat Selaras with Heuristic Classic Method, Tabu Search Algorithm Method and Active Scheduling Method to Minimize Production Makespan.

Gozali, L., Ariyanti, S., & Tanujaya (2014), A. USULAN PENJADWALAN MESIN CUTTING KERAMIK PARALEL DENGAN PENDEKATAN ALGORITMA TABU SEARCH DI PT. X. Jurnal Teknik Industri. Universitas Tarumanagara. Jakarta

Vania, E., (2020), PENJADWALAN PRODUKSI FLOWSHOP MENGGUNAKAN ALGORITMA CDS, TABU SEARCH DAN GENETIKA (STUDI KASUS: CV MEGA ABADI), Thesis, Universitas Tarumanagara, 2020

Vollman, T.E., W.L. Berry, D.C. Whybark, 1997. Manufactur-ing Planning and Control Systems, 4th Edition. Irwin,Homewood,

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