

Time and Cost Optimization Using Scheduling Job Shop and Linear Goal Programming Model

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Abstract— Time and cost optimization is a way to determine the optimal time and cost to use. Usually the faster the time the cost is more. To determine the time of peractivity used schedulling jobshop. The problem is whether the system that companies do so far is the best system or not. Activity issues include how to design some regulatory activities while minimizing total time, and total distribution costs. This problem is encountered in the case of Surabaya Container. In this paper, we discussed how to apply goal programming method to create activity model with company's constraints to obtain more optimal results. By developing a pre-existing activity model and using the help of the LINGO 11.0 program, the determination of the route with the goal programming method can be completed. The results obtained show that activity is formed with time, and the minimum cost. Moreover, in this paper will also compare the scheduling flow shop and job shop. Job shop produces less time than flow shop.

Keywords—*Flow Shop; Goal Programming; Job Shop*

I. INTRODUCTION

Preparation of a good scheduling is a very important thing in the industrial world. Utilizing the right time can improve the effectiveness of performance so as to reduce costs. Scheduling can be interpreted as the allocation of some work in a series of machines, each machine only doing one job at a time. In general, scheduling is a problem in terms of sorting operations and allocating them into specific time slots without prolonging the technical constraints and capacity constraints[1].

Time and cost are the main elements in the planning of distribution activities. Cost involved in the time constraints of the implementation of distribution activities. This planning takes into consideration the time of distribution and cost in order to minimize distribution time and minimize costs. To achieve that goal, an optimization of several factors that affect the distribution process is needed. Factors used in this distribution planning optimization are inventory data, demand data, time distribution data and cost data.

Several approaches have been developed to solve the distribution planning problem. Bhargava et al [2] uses the Goal Programming method to complete multi-objective food product distribution planning. The purpose of the research is to help determine the amount of product to be distributed so as to meet the achievement of total product distribution and generate maximum profit and can minimize the total cost of

manufacturing. From the results of this research, the authors say that the Goal Programming model can also be used as decision making[3].

Another study was conducted by Nasruddin et.al [4] applying the Goal Programming method to solve the multi-objective problems of production planning. This study aims to minimize production costs and maximize profits by optimizing product compounds to produce good product quality. From the results of the study, author said that the method of Goal Programming can be used for agricultural planning in reducing production costs so as to increase profits. The method of Goal Programming is a method capable of solving cases that have more than one goal to be achieved[5].

Goal programming is an extension of the linear programming method so that all assumptions, notations, mathematical model formulations, mathematical formulation procedures and solutions are no different. The advantages of goal programming compared with linear programming that is to solve the problem with many goals (multi-objective programming). Therefore, in this paper will be applied goal programming to optimize the time and cost of activity with job shop scheduling.

II. LITERATURE REVIEW

A. Business Process Model

The business process model is a set of activity based on the process so that the activity can be analyzed and improved[6]. The process of modeling can be done based on the event log that has information when the activity is done, who is doing, and the name of the activity. In its implementation BPM is concerned with many management sciences where the technical and process influences to suppress the quality of an analytical and analytical approach as well as responsibility in terms of quality improvement. The BPM techniques, namely business process modeling notation (BPMN), UML diagrams, flowcharts, data flow diagrams (DFD) workflows, etc[7].

B. Event Log

Event Log contains all the activities that are processed. Event Log give information for instance organizational information concerning the performers of each activities. Event logs are divided into 3 parts, namely case, trace and activity[8].

- Case and Trace

Case explained that the process is done in one time from start to complete. While the trace is the path passed.

Examples that exist in the event log:

1. There are 3 trace, that is: quarantine; red line, dry; red line, and quarantine; green line.
2. There are 83 cases, that is: quarantine; red line 21 times, dry; red line 32 times, and quarantine; green line 30 times.

- Activity

Activity shows the process being performed and recorded start and completion time.

C. Goal Programming

Is a method used as a decision to analyze and create solutions problems that involve many goals to obtain optimal problem solving. The basic approach of goal programming is to set a goal expressed with a certain number for each goal, to formulate a function of purpose, and then to seek a solution by minimizing the number of (deviated) deviations from the objective function. The basic approach of goal programming is to set a goal expressed with a certain number for each goal, to formulate the objective function and then to seek a solution by minimizing the number of deviations from the objective function[4]. To perform the method of Goal Programming first determines the decision variables, objective functions and constraints of the issues raised.

a. General Model of Goal Programming

The general model of goal programming is given as follows, for example in the company there are circumstances:

$$Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots + C_lX_l \quad (1)$$

ST :

$$a_1X_1 + a_2X_2 + a_3X_3 + \dots + a_iX_i \leq Y \quad (2)$$

$$b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_iX_i \leq Y(3)$$

Where Z is an objective function, ST is a constraint, X_i is the time / cost for an activity, Y is the target to be achieved. Function objectives and limitations above is a formula in the form of Linear Programming method. The next step is to change the formulas that form Goal Programming. The formula of change, there is the addition of a variable called the deviation variable. The deviation variable is used for the function of a new function with a predetermined variable deviation variable [2]. Writing the formula objective function with variable deviation variable is as follows:

$$\text{Min } Z = \sum_{i=0}^n C_i P_i (d_i^+ + d_i^-) \quad (4)$$

Where P_i the priority level of each goal, C_i is a constant of non-negative for weighting and d_i^+ also d_i^- is a deviation variable.

D. Flow Shop Scheduling

In the flow shop, all jobs tend to have the same sequence of operations (routing)[9]. Flow shop flow pattern can be seen

in Figure 1. Flow shop is divided into two types, namely pure flow and general flow shop. At pure flow shop every work will pass every machine contained in the same process flow as in Figure 2. While in general flow shop tasks that come into the flow shop do not have to be done on all types. Can be seen in Figure 3.

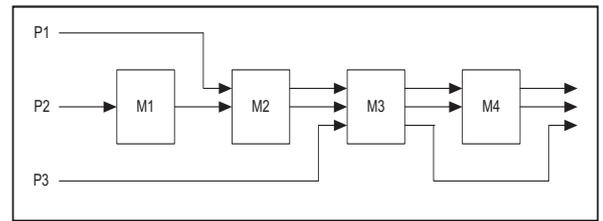


Figure 1. Flow Shop flow pattern

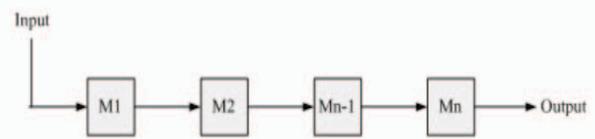


Figure 2. Pure Flow flow pattern

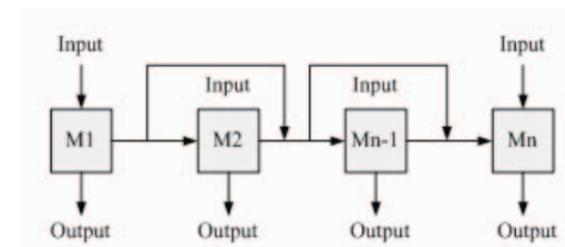


Figure 3. General Flow flow pattern

E. Job Shop Scheduling

Job shop scheduling is the job scheduling where the sequence of operation/production process of a regular job is different from the sequence of the operation process/other job production. This job shop aims to avoid conflict of one resource use by two same operations at the same time[10].

In the job shop process flow pattern, each job has a unique sequence of operations. Each job moves from one machine to another with a different pattern. Job Shop Flow pattern can be seen in Figure 4.

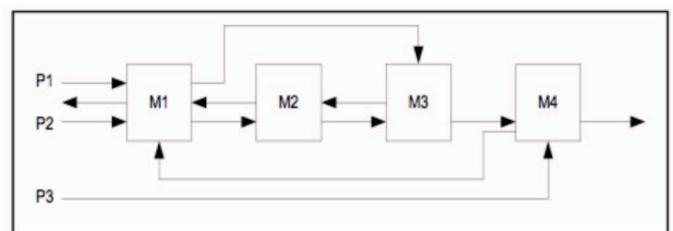


Figure 4. Job Shop flow pattern

The scheduling performance measurement criteria, as follows:

- Makespan

The amount of time required to complete the entire process on the scheduled part from the time of processing of the first part until the last part has been processed.

$$C_{maks} = Maks\{C\} \quad (5)$$

Where C_{maks} is the total time required to complete all tasks, from the first task to the n^{th} task.

- Maximum Flowtime (Fmaks)

$$F_{maks} = M_{maks}\{F\} \quad (6)$$

Where F_{maks} is the time period in which a task starts ready to be processed to completion.

- Mean Flowtime
This criterion shows the average time spent on each part on the factory floor. Flowtime is the completion time difference with ready time.

$$F = \frac{1}{n_{i=1}} \sum_{i=1}^n F_i \quad (7)$$

Where F_i is the flowtime and n is the number of parts produced.

- Mean Weight Flowtime
The definition of mean weight flowtime is similar to the mean flowtime, but consider the job priority of each job in its calculations.

$$F_w = \frac{\sum_{i=1}^n W_i F_i}{\sum_{i=1}^n W_i} \quad (8)$$

Where W_i is the weight flowtime and F_i is the flowtime for n is the number of parts produced.

- Maximum Lateness
Is the greatest lateness value. Lateness is the difference between the time of completion of the job and the due date. Lateness is negative if the job completion time is earlier than the due date and is positive if completed after due date.

$$C_{maks} = Max\{L_i\} \quad (9)$$

Where C_{maks} is the makespan and L_i is the Lateness.

- Mean Tardiness
Is the average delay (positive lateness) for all scheduled jobs.

$$T_s = \frac{1}{n} \sum_{i=1}^n T_i \quad (10)$$

Where T is the tardiness for all scheduled jobs.

- Mean Weight Tardiness
It is the average delay of priority factor of workmanship by entering in the calculation.

$$T_w = \frac{\sum_{i=1}^n W_i T_i}{\sum_{i=1}^n W_i} \quad (11)$$

Where W_i is the weight tardiness and T_i is tardiness for n is the number of parts produced.

- Number of Tardy Job
Indicates the quantity (number) of jobs that are delayed (positive lateness).

$$N_T = \sum_{i=0}^n S_i \quad (12)$$

Constraints:

$$S_i = 1 \text{ if } T_i > 0$$

$$S_i = 1 \text{ if } T_i = 0$$

Where N_T is number of tardy job and S_i is the constraint.

III. THE PROPOSED METHOD

A. Step Scheduling

Take trace quarantine, red line, dry line, red line, and quarantine; green line. Each has a duration and a peractivity cost. The purpose of this scheduling is to parallel activity to more optimal time spent. Because the activity of goods can not be parallelized, then what will be paralleled is the document activity with the goods.

B. Calculate The Average Time dan Cost

The average value of each activity will be used as input goal programming. To calculate the average time I use PROM[11] and average cost using the usual average calculation in excel.

C. Optimization Using Goal Programming

In this paper, we use non-preemptive goal programming (weighting). In this method each coefficient on the objective function can be given the same weight or vary according to importance. At this stage will be done formulation of all boundaries and parameters needed in the process of analysis of existing problems into a mathematical model. The purpose of this data modeling is to determine the decision variables, objective function and constraints of the problems obtained.

1. Decision variables
The decision variable is an unknown variable. Variable decision of this research is time and cost to be known its value.
2. Objective Function
The objective function of this paper is to minimize the time and cost of activities.
3. Constraint
Constraint is a variable that becomes a barrier in achieving the purpose function. The Constraint of this paper are the average of time and cost per activity.

Then from the model Linear Programming is converted into Goal Programming model by adding deviation variables and formed a new objective function.

4. Determine the deviation variable

The deviation variable is a deviation of the goals to be achieved, which is used to define the opposite objective of the objective function. Differentiated into two, ie the upper deviation (positive) to accommodate the deviation above the achievement of the target and the deviation below (negative) to accommodate the deviation below the achievement of the target. Constraints related to the purpose function must be added with the deviation variable.

IV. EVALUATION

A. Dataset

The dataset used is event log from PETIKEMAS Surabaya. We only take trace quarantine and customs. There are 3 trace that will be in the optimization, namely trace quarantine; red line, trace dry; red line and trace quarantine; green line. Each trace has a different number of cases. For trace quarantine: red line there are 21 cases, trace dry; red line there are 32 cases, and trace quarantine; green line there are 30 cases. The total case is 83 cases. This dataset consists of case ID, activity name, start time, stop time and cost that can be seen on Table 2.

B. Paralel Time

By applying the scheduling job shop, then we can make the activity time to be parallel. But in this dataset only document activity with activity of goods that can be paralleled. The parallel activity is as follows:

1. Create_document_KH/KT with Stack_Container_in_Yard_From_Quarantine
2. Create_document_LHP with Bring_Container_from_Yard_to_Behandle

This aims to make the production time becomes more optimal.

C. Comparison of Job Shop with Flow Shop

The result of comparison between flow shop job shop is job shop produces less time compared with flow shop. This is because with job shop, document activity with goods can be paralleled. Comparison of time between Flow Shop with Job Shop can be seen on Table 1.

Table 1. Comparison of Flow Shop with Job Shop

Trace	Time (Hours)	
	Flow Shop	Job Shop
1	212,98	211,47
2	237,82	235,46
3	237,84	235,51

From Table 1, can be seen with the time jobshop to complete 1 trace faster than the flow shop. This is because the activity of the document and the activity of goods are parallelized. PROM model can be seen on Figure 5 and Figure 6.

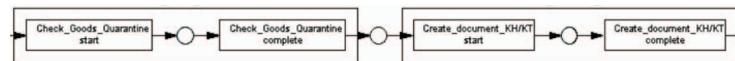


Figure 5. Flow Shop

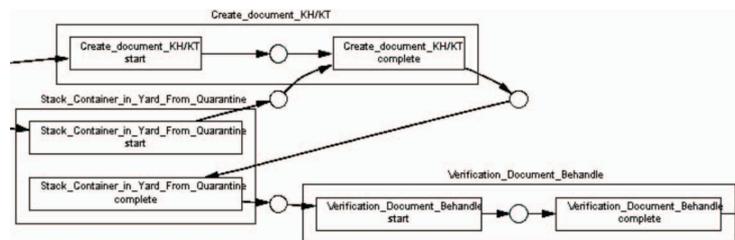
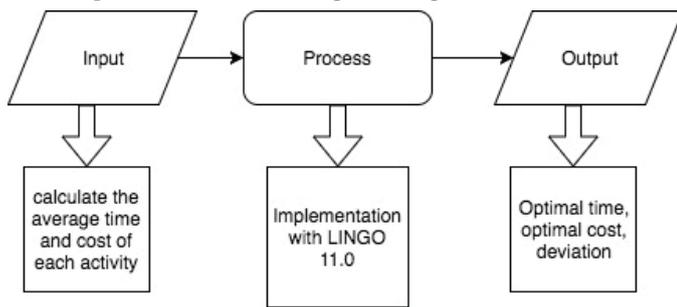


Figure 6. Job Shop

Table 2. Dataset

Case ID	Activity	Time Start	Time Complete	Cost
4484470	Discharge Container	01/02/16 06.43	01/02/16 06.49	658,93
4484470	Bring_Container_to_Yard	01/02/16 06.49	01/02/16 07.01	74,99
4484470	Stack_Container_in_Yard	01/02/16 07.01	01/02/16 07.04	28,99
4484470	Verification_Document Behandle	01/02/16 07.04	05/02/16 23.08	5,77
4484470	Create_Job_Order_Document Behandle	05/02/16 23.08	12/02/16 20.09	793,18
4484470	Stack_Container_in_Behandle Area	12/02/16 20.09	16/02/16 18.08	567,23
4484470	Check_Goods_Behandle	16/02/16 18.08	16/02/16 20.25	1418,07
4484470	Create_document_LHP	16/02/16 20.25	17/02/16 01.00	30105,07
4484470	Bring_Container_from_Yard_to_Behandle	16/02/16 20.25	17/02/16 07.46	484,34
4484470	Stack_Container_in_Yard From Behandle	17/02/16 07.46	17/02/16 07.53	352,87
4484470	Create_document_SPPB	17/02/16 07.53	18/02/16 05.39	3507,53
4484470	Create_Job_Order_Document Delivery	18/02/16 05.39	19/02/16 12.39	66315,17
4484470	Truck in	19/02/16 12.39	20/02/16 07.14	23296,26
4484470	Dispatch_WQ_Delivery to CHE	20/02/16 07.14	20/02/16 07.15	1276,68
4484470	Determine_Container_Type	20/02/16 07.15	20/02/16 07.18	2594
4484470	Determining Dry	20/02/16 07.18	20/02/16 07.20	23,37
4484470	Decide_Task_Before_Lift Container	20/02/16 07.20	20/02/16 07.22	3320,51
4484470	Lift_on_Container_Truck	20/02/16 07.22	20/02/16 07.25	23,97
4484470	Truck_Go_To_Gate_Out	20/02/16 07.25	20/02/16 09.01	3148,25
4484470	Check_Container_before Truck out	20/02/16 09.01	20/02/16 09.03	2813,63
4484470	Truck Out	20/02/16 09.03	20/02/16 09.04	22443

D. Completion with Goal Programming



The time of each activity to be used in the Goal Programming formulation is the average of the activity of all cases. So is the cost. The average of each activity in trace 3 can be seen in Table 3.

Table 3. Average time and cost

Activity	Time (minutes)	Cost (\$)
Discharge Container	5,64	563,81
Bring Container to Yard	24,04	65,32
Stack Container in Yard	2,52	25,25
Verification Document Quarantine	2139,48	172,74
Create Job Order Document Quarantine	40,07	191,15
Bring Container from Yard to Quarantine	96,96	184,69
Stack Container in Quarantine Area	2,40	179,53
Check Goods Quarantine	48,08	371,37
Create document KH/KT	96,16	451,22
Stack Container in Yard From Quarantine	1201,95	174,59
Verification Document Behandle	2350,96	7,00
Create document SPPB	576,94	2613,38
Create Job Order Document Delivery	650,26	38278,90
Truck in	1746,43	12750,86
Dispatch WQ Delivery to CHE	1,31	1072,53
Determine Container Type	2,73	2456,12
Determining Dry	2,32	20,05
Decide Task Before Lift Container	1,49	2549,08
Lift on Container Truck	2,50	20,88
Truck Go To Gate Out	65,49	2533,00
Check Container before Truck out	1,48	2342,26
Truck Out	1,48	12421,83
GOAL	8964,52	79445,55

Table 3 shows some activity from the event log with the average time and cost of each activity. Where time with units of minutes and costs with units of USD.

The steps to be taken in Goal Programming optimization are as follows:

1. Determining the purpose function. The purpose function is the difference between the number of requests and the amount of time and cost allocations. For the purpose of minimizing the time denoted by D1plus and D1minus. While the objective function of minimizing cost is denoted by D2plus and D2minus. $min p1^+D1^+ + p1^-D1^- + p2^+D2^+ + p2^-D2^-$ (13)
2. Formulating time constraints. This time constraints are used so that the time of the activity does not exceed the time available.

$$\sum_{i=1}^n (x_i) - D1^+ + D1^- = y \tag{14}$$

Where n the number of activities and y is the target. Lingo formulation:

$$a*x1 + b*x2 + \dots + xn - D1plus + D1minus = y \tag{15}$$

x1, x2, xn is the amount of time it takes peractivity. While D1plus and D1minus is a deviation.

3. Formulate cost constraints. These cost constraints are used for the cost to perform activities not to exceed the costs that have been provided.

$$\sum_{i=1}^n (x_i) - D2^+ + D2^- = y \tag{16}$$

Where n the number of activities and y is the target. Lingo formulation:

$$a*x1 + b*x2 + \dots + xn - D2plus + D2minus = y \tag{17}$$

x1, x2, xn is the amount of time it takes peractivity. While D2plus and D2minus is a deviation.

4. Determine the constraint function. The constraint function is the assumption that all activations should be done at least once per case.

$$xn \geq 1 \tag{18}$$

E. Result Goal Programming

After the mathematical formulation we get the solution of the amount of time and cost for each trace. These results can be seen on Table 4.

Table 4. Result Goal Programming

Trace	D1 plus	D1 minus	D2 plus	D2 minus	Time (minutes)	Cost (\$)
1	96,29	0	0	0	12592	92862,18
2	139,4	0	0	0	13991,56	84931,82
3	96,16	0	0	0	8868,35	79445,55

Table 4 shows the existence of deviation that affect the time and cost of each activity. For that, the end result is, the initial target of time and cost is reduced by the existing deviation. Reduced because the deviation takes place in positive deviations in which the deviation should be minimized. In addition, the objective function also affects the optimization of time and cost. The greater the objective value the time and cost will be more optimal.

V. CONCLUSION

This paper compares the scheduling flow shop with job shop. Flow shop takes more time because the activity is done by sequence. While the job shop is more flexible because it can make 2 activities performed simultaneously (parallel). However, in the case of PETIKEMAS Surabaya only document activity with activity of goods which can be done simultaneously. After doing scheduling testing with job shop produce 1-2 hours faster than flow shop scheduling. Then proceed with the optimization of time and cost using Goal Programming non-preemptive (weighting) that result in more optimal time and cost. In trace 1 the optimum time is 12592 minutes from the initial 12688,3 minutes. For trace 2 the optimum time is 13991,56 minutes from initially 14130,97 minutes. As for trace 3, the optimal time is 8868.35 minutes from the initial 8964.52. However, for the third cost of this trace initial target is to meet the optimal cost. So the cost is only slightly reduced even almost no deviations. In addition, the objective function also affects the optimization of time and cost. The greater the objective value the time and cost will be more optimal.

REFERENCES

- [1] V. Agarwal, R. K. Upadhyay, and B. K. Pathak, "A State of Art Review on Time Cost Trade off Problems in Project Scheduling," *Int. J. Appl. or Innov. Eng. Manag.*, vol. 2, no. 5, pp. 37–44, 2013.
- [2] A. K. Bhargava, S. R. Singh, and D. Bansal, "A Fuzzy Goal Programming Approach for Food Product Distribution of Small and Medium Enterprises," vol. 9, no. 2, pp. 157–166, 2015.
- [3] M. Tamiz, D. Jones, and C. Romero, "Goal programming for decision making: An overview of the current state-of-the-art," *Eur. J. Oper. Res.*, vol. 111, no. 3, pp. 569–581, 1998. [https://doi.org/10.1016/s0377-2217\(97\)00317-2](https://doi.org/10.1016/s0377-2217(97)00317-2).
- [4] N. Hassan, K. Hassan, S. Yatim, and S. Yusof, "Optimizing fertilizer compounds and minimizing the cost of cucumber production using the goal programming approach," *Am. J. Sustain. Agric.*, vol. 7, no. 2, pp. 45–49, 2013.
- [5] D. R. Catchpole, P. Kennedy, D. B. Skillicorn, and S. Simoff, *The curse of dimensionality: A blessing to personalized medicine*, vol. 28, no. 34. 2010. <https://doi.org/10.1200/jco.2010.30.1986>.
- [6] Hermawan, R.Sarno, *Developing Distributed System with Service Resource Oriented Architecture*, TELKOMNIKA (Telecommunication Computing Electronics and Control), 10 (2), pp.389, 2012. <http://dx.doi.org/10.12928/telkomnika.v10i2.815>.
- [7] R. Sarno, Y. A. Effendi, and F. Haryadita, "Non-Linear Optimization of Critical Path Method," *3rd International Conference on Science in Information Technology (ICSITech)*, no. 31, 2017. <https://doi.org/10.1109/icsitech.2017.8257091>.
- [8] R. Sarno, F. Haryadita, Kartini, Sarwosri, and A. Solichah, "Business process optimization from single timestamp event log," *Proceeding - 2015 Int. Conf. Comput. Control. Informatics Its Appl. Emerg. Trends Era Internet Things, IC3INA 2015*, pp. 50–55, 2016. <https://doi.org/10.1109/ic3ina.2015.7377745>.
- [9] V. Modrák and R. Pandian, "Flow shop scheduling algorithm to minimize completion time for n-jobs m-machines problem," *Teh. Vjesn.*, vol. 17, no. 3, pp. 273–278, 2010.
- [10] D. Applegate and W. Cook, "A Computational Study of the Job-Shop Scheduling Problem," *ORSA Journal on Computing*, vol. 3, no. 2, pp. 149–156, 1991. <https://doi.org/10.1287/ijoc.3.2.149>.
- [11] W. M. P. van der Aalst, "Process-aware information systems: Lessons to be learned from process mining," *Trans. Petri Nets Other Model. Concurr. II*, pp. 1–26, 2009. https://doi.org/10.1007/978-3-642-00899-3_1.