Goal Programming to Optimize Time and Cost for each Activity in Port Container Handling

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Abstract – **The services of port in Indonesia are increasing from year to year. The traffic of port is increasingly crowded with the number of boats coming to load and unload processes. A lot of ship queues result in delay when exceeding due date from the date of the agreement will cause the higher cost to be issued which is called demurrage. To reduce the costs incurred and the length of queue time on the scheduling at the port, we used Goal Programming (GP). Goal Programming is an algorithm that solves linear programming problems using mathematical formulation to get solutions in getting goals. In this study, optimizing 43 activities and 7 trace variations on loading and unloading activities of container terminal services from events log. The goal programming model from 43 activities has been implemented using Lingo software to obtain objective value in achieving the objectives of each activity used to determine activities that have a major influence on the delay in loading and unloading activities. The result of Goal Programming is that there are two activities which have very high deviation, therefore both of activities are evaluated in performance on container activity.**

Keywords—event log; goal programming; port container handling; time and cost optimization

I. INTRODUCTION

Scheduling is the process of organizing, controlling and optimizing work and work load in a production process at the company, especially container companies in the port. Scheduling at the port has an increasingly congested problem in line with the increase in the company's production capacity which causes the raw material demand for production also increases. Port traffic is increasingly crowded with the number of boats coming to load and unload process. A lot of ship queues result in delay when exceeding due date from the date of the agreement will cause the higher cost to be issued which is called demurrage to be paid due to delay in loading and unloading activities [1].

Executed process businesses are recorded in the event log. Event log: case ID, activity, start time, end time, cost, resource. Based on this event log, we use it to next step, optimization. In the optimization, we only pay attention to timestamp and cost [2].

Business process in PCT (Port Container Terminal) consists of 43 activities, including message. From Entry document via PDE as first activity until Truck out as last activity. Based on all activities, we do research to determine the optimal time and cost.

To reduce the costs incurred and the length of time the queue optimization is done on the scheduling at the port, we used Goal Programming (GP). Goal programming is a technique often used in engineering design activities primarily to find a compromised solution which will simultaneously satisfy a number of design goals [3]. Goal programming can provide an optimal solution in cost and time optimization on port scheduling.

In this research, optimizing 43 activities and 7 trace variations on loading and unloading activities of container terminal services from events log. The goal programming model from 43 activities has been implemented using Lingo software to obtain objective value in achieving the objectives of each activity used to determine activities that have a major influence on the delay in loading and unloading activities. Therefore this paper represents a method to calculate data from event log which is used to get bad time activity for evaluated the performance.

II. LITERATURE REVIEW

A. Event Log

The starting point of analysis is an event log, which is basically a set of process executions capturing the different business activities. However, typical event log will contain much more information, for instance organizational information concerning the performers of the different activities. Event log is divided into three parts i.e. Case, Trace, and Activity.

- Case and Trace

A case is a record of events related to a single executed process instance. Case can be described as the production process of one stuff. Whereas trace records sequence of events that belong to the same case [2].

For example in event log:

$$L = [\langle a, c, d\rangle^{15}, \langle b, c, d\rangle^{10}, \langle a, c, d\rangle^{20}, \langle b, c, e\rangle^{25}] \quad (1)$$

In that event log:

1. Contains 4 trace .i.e. (*a*,*c*,*d*), (*b*,*c*,*d*), (*a*,*c*,*d*),(*b*,*c*,*e*)
2. Contains 147 case .i.e. (*a*,*c*,*d*) executed 15 time, (*b*,*c*,*d*) 10 time, (*a*,*c*,*e*) 20 time, and (*b*,*c*,*e*) 25 time.

- Activity

Activity is part of event log presenting sub of production process of a stuff or certain production process.

Example in event log in Equation 1, the event log contains five activities i.e. $\{a, b, c, d, e\}$.

Importance information is obtained by extract from the event logs to modeling the workflow of a business process [4], [5]. This is double time-stamped event log containing more than one organization executing activities in event log, where the event logs recording each container service activity in each case with more than one organization [6], [7]. For the model of container service activity events log refer to Table I.

TABLE I. EXAMPLE EVENTS LOG IN CASE ID 4572761

Case ID	Activity	Time	Cost
4572761	Document_Entry_via_PDE	2/23/2016 7:40	0
4572761	Request_Behandle	2/23/2016 7:41	0
4572761	Vessel_Berthing_Process	2/23/2016 10:20	51214
4572761	Discharge_Container	2/23/2016 19:17	900.2931
4572761	Bring_Container_to_Yard	2/23/2016 19:49	74.99
4572761	Stack_Container_in_Yard	2/23/2016 19:51	28.99
4572761	Approve_Behandle	2/24/2016 0:20	1.698598
4572761	Verification_Document_Behandle	2/24/2016 4:41	9.681104
4572761	Create_document_SPPB	2/24/2016 6:51	2090.441
4572761	Send_SPPB_Info	2/24/2016 6:52	0
4572761	Create_Job_Order_DocumentDelivery	2/24/2016 9:18	57.84699
4572761	Send_Job_Order_Delivery_Info	2/24/2016 9:20	
4572761	Truck_in	2/24/2016 11:55	20.4832
4572761	Dispatch_WQ_Delivery_to_CHE	2/24/2016 11:56	1.745946
4572761	Determine_Container_Type	2/24/2016 11:59	4.849932
4572761	Determining_Dry	2/24/2016 12:01	23.37
4572761	Decide_Task_Before_Lift_Container	2/24/2016 12:02	2.831622
4572761	Lift_on_Container_Truck	2/24/2016 12:05	23.97
4572761	Truck_Go_To_Gate_Out	2/24/2016 12:27	2.948159
4572761	Check_Container_before_Truck_out	2/24/2016 12:29	2.830737
4572761	Truck_Out	2/24/2016 12:30	19.34071

From Table I, we get information about time and cost that will be used as a variable in goal optimizer. The time format in the table must be changed to be processed in the lingo application, therefore the math formulation sojourn time is done by reducing the finished time with the initial time. For the result refer to Table II.

TABLE II. SOJOURN TIME IN CASE ID 4572761

Case ID	Activity	Sojourn Time (Minute)
4572761	Document_Entry_via_PDE	74
4572761	Request_Behandle	9518
4572761	Vessel_Berthing_Process	32223
4572761	Discharge_Container	1931
4572761	Bring_Container_to_Yard	128
4572761	Stack_Container_in_Yard	16161
4572761	Approve_Behandle	15661
4572761	Verification_Document_Behandle	7809
4572761	Create_document_SPPB	16
4572761	Send_SPPB_Info	8786
4572761	Create_Job_Order_DocumentDelivery	127
4572761	Send_Job_Order_Delivery_Info	9269
4572761	Truck_in	81
4572761	Dispatch_WQ_Delivery_to_CHE	150
4572761	Determine_Container_Type	138
4572761	Determining_Dry	92
4572761	Decide_Task_Before_Lift_Container	157
4572761	Lift_on_Container_Truck	1347
4572761	Truck_Go_To_Gate_Out	97

B. *Goal Programming*

The Non Preemptive Goal Programming is a problem solving technique involving the plurality of targets using mathematical formulation to get solutions in getting goals drom linear programming.[3], [8] The basic approach used in goal programming is to minimize the deviation between defined goals and the effort to be performed in a set of system constraints. Thus, the target program model involves only minimizing problems [9]–[11]. GP model involving criteria on the economic development (GDP) [12], Nurse scheduling [13], and Scheduling IT Staff [14].

Formulation Goal Programming :

$$Z_{min} = \sum_{k=1}^{K}(d_k^+ + d_k^-) \quad (2)$$

Constrain :

$$\sum_{j=1}^{n} c_{jk}x_j - (d_k^+ - d_k^-) = b_k \quad (3)$$

$$\forall x_j, d_k^{+/-} \geq 0 \quad (4)$$

Where,

$x_1, x_2, \ldots, x_n$ = decision variables

c_{jk} = coefficient xj = (j = 1,2,3, ..., n) in the objective function in each k-goal (k = 1,2, ..., k)

b_k = target for k-goal

$d_k^{+/-}$ = the variable of deviation that represent the level of achievement exceeds the target and the achievement is below the target

Steps formation of Goal Programming model include:

1. Determination of decision variables, namely the parameters that affect the decision
2. Function Formulation Purpose
3. Establish mathematical equations for defined purposes each objective function should be described as a function of decision variables.

   $$gi = fi\,(x) \quad (5)$$

   where,

   $fi\,(x)$ = function of decision variable of destination to i.

   Each function must have a right-hand side and a left-hand segment.

   $$fi\,(x) + di^- - at^+ = bi \quad (6)$$

   where i = 1,2,3, ... m

   di^- denotes the amount of negative deviation $fi\,(x)$ of bi,

   while the value at^+ denotes the magnitude of the positive deviation.
4. Choosing an absolute goal, which is the goal that must be met and defined as a priority to form a function of achievement.
5. Set objectives at the right priority level

6. Simplify the model. This step needs to be done to get a model large enough so that the model can represent all the goals.
7. Compile the Achievement function.

Simplex algorithm is used to solve linear problem of Goal (Multi Objectives) Programming by using decision variable more than two. The steps of completion of Goal Programming with simplex algorithm method are:

1. Form the initial simplex table
2. Select the key field where *Cj-Zj* has the largest negative value. This key column is called a pivot column
3. Select the line based on *bi* / *aij* with the smallest ratio where bi is the right side value of each equation. This key line is called a pivot line.
4. Look for a canonical system where the value of a pivot element is worth 1 and another element is zero by multiplying the pivot row by -1 and then appending it with all elements in the first row. Thus obtained table simplex iteration I.
5. Optimality check, ie see if the solution is feasible or not. The solution is said to be feasible when the variable is positive or zero.

III. PROPOSED METHOD

The proposed method work flow method is referring to Fig. 1.

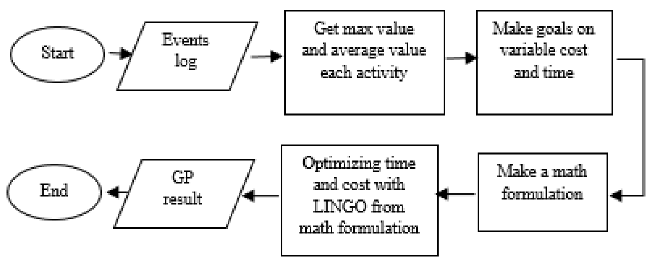


Fig.1. Flowchart of Proposed Method

From Fig.1, the Flowchart of Proposed Method is as follows:

1. Getting event log data as in Table I.
2. Obtain the maximum value and average of each activity contained in the event log for the next process.
3. Formulate a mathematical formulation for the next process, because goal programming is part of linear programming that can solve a solution using mathematical way
4. The mathematical formulation that has been created will be used as input on the lingo program.

IV. EXPERIMENTS USING LINGO

LINGO is a simple tool for utilizing the power of linear and nonlinear optimization to formulate large problems concisely, solve them, and analyze the solution. In this case used goal programming based on linear programming.

Based on the proposed method, the first step in the optimization of time and cost is to know the maximum and average of each activity in the event log. For the result refer to Table III.

The next step is to determine the goal for goal programming algorithm, in this stage is chosen average each activity in time and cost variables as the goal to be optimized. Then proceed to formulate the goals and variables into the math. The formula of the prepare tools activity is as follows :

$$Min\ Z = (d11+d12+d21+d22); \quad (7)$$

$$157*x1+d11-d12=150; \quad (8)$$

$$93.2959*x1+d21-d22=77.82816; \quad (9)$$

$$93.2959*x1+d21-d22=77.82816; \quad (9)$$

$x1>=1;$

$d11>=1;$

$d12>=1;$

$d21>=1;$

$d22>=1$

The above formula is included in lingo program for goal programming process

Where,

d11, d12, d21, d22 are the deviation of goal programming formulation according to the steps of goal programming. *d11* for positive time, *d12* for negative time, *d21* for positive cost, *d22* for negative cost.

X1 declare to activity.
157 is maximum of time in prepare tools activity.
150 is average of time in prepare tools activity or goal of time in this case.
93.2959 is maximum of cost in prepare tool activity
77.82816 is average of cost in prepare tools activity or goal of cos in this case.

To show mathematical function in Goal programming, Fig.2 shows work area in Lingo which are used to solve linear problem related to the goal for time and cost optimization.

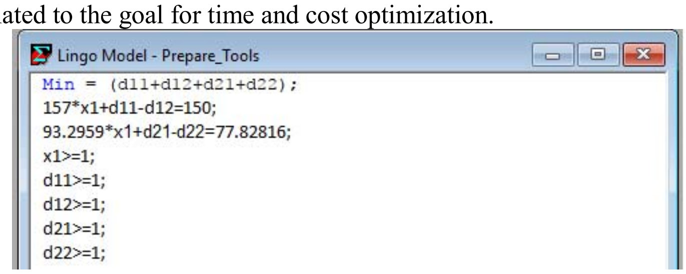
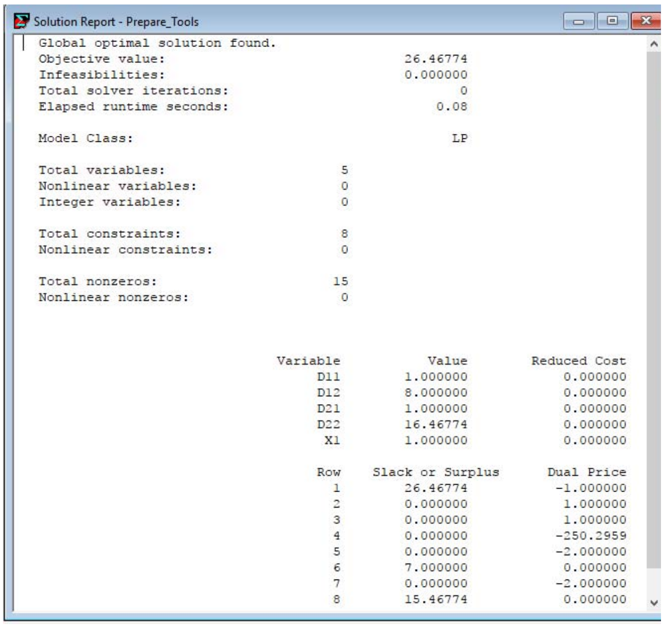


Fig.2 Code in Lingo

Fig.3 shows the result for activity 'Prepare Tools' in Lingo Area. In this paper, we do the same method for all others activities.

TABLE III. RESULT MAX VALUE AND AVERAGE VALUE

Activity	Max Time	Max Cost	Average Time	Average Cost
Document_Entry_via_PDE	120	0	90.10749	0
Request_Behandle	10727	0	7084.403	0
Vessel_Berthing_Process	118676	72785.01	27543.24	54202.60618
Discharge_Container	471.8067	14326	1390.242	503.4188996
Bring_Container_to_Yard	180	81.09	150.0711	61.78317151
Stack_Container_in_Yard	1035656.916	19.34	51670.58	23.57541849
Approve_Behandle	1003625.693	1.774283572	45459.12	1.84145807
Verification_Document_Behandle	500451.6614	7.022202946	23870.06	6.794385433
Create_document_SPPB	1042.607981	2451.491284	47.22232	2663.689672
Send_SPPB_Info	563008.1221	0	25501.39	0
Create_Job_Order_Document_Delivery	179.9429154	28.4912231	150.0689	38.028498
Send_Job_Order_Delivery_Info	1406832.249	0	83735.22	0
Truck_in	103.8307679	23.6736852	79.75201	12.64509848
Dispatch_WQ_Delivery_to_CHE	188.9611199	1.44170954	164.9259	1.120951498
Determine_Container_Type	158.482397	3.561517618	134.9474	2.538619323
Determining_Dry	99.66024009	23.37	89.92336	18.35116129
Decide_Task_Before_Lift_Container	779.2972416	1.619402982	167.1964	2.517147019
Lift_on_Container_Truck	105323.8554	15.98	2731.811	19.57782267
Truck_Go_To_Gate_Out	99.6619676	2.173856609	89.89137	2.513133217
Check_Container_before_Truck_out	99.65479667	0.373049793	89.92169	2.525677966
Truck_Out	0	5.48962939	0	12.66034051
....	....	....	....	....
Prepare_Tools	156.7077411	93.29585582	149.6192	77.82816193


Solution Report - Prepare_Tools

```
Global optimal solution found.
Objective value:                      26.46774
Infeasibilities:                      0.000000
Total solver iterations:                     0
Elapsed runtime seconds:                  0.08

Model Class:                                LP

Total variables:                 5
Nonlinear variables:             0
Integer variables:               0

Total constraints:               8
Nonlinear constraints:           0

Total nonzeros:                 15
Nonlinear nonzeros:              0

              Variable           Value        Reduced Cost
                   D11        1.000000            0.000000
                   D12        8.000000            0.000000
                   D21        1.000000            0.000000
                   D22        16.46774            0.000000
                    X1        1.000000            0.000000

                   Row    Slack or Surplus      Dual Price
                     1        26.46774           -1.000000
                     2        0.000000            1.000000
                     3        0.000000            1.000000
                     4        0.000000           -250.2959
                     5        0.000000           -2.000000
                     6        7.000000            0.000000
                     7        0.000000           -2.000000
                     8        15.46774            0.000000
```

Fig.3. Result of prepare tools

In Fig.3 there is information that the "Prepare Tool" activity has an objective value of 26.46774. Which is the objective value used as the reference value in determining the outcome of the goal programming process. If wants to get the desired result the objective value is subtracted to the maximum value of the activity being analyzed. Then the target value is reached. To find out the reductions and additions to the 'Prepare Tool' activity by looking at which deviation variables are experiencing changes other than value 1. The "Prepare Tools" activity shows a change in *D12* and *D22* which indicates a negative result. If it produces a value on that variable then the objective value will be subtracted to the maximum value as described before. And if it shows the change in the variable *D11* and *D21* then the value on the variable will be added to the maximum value on the activity being done goal programming process. To find out how much activity changes in order to produce optimal results on the optimization of cost and time. We do the same method to all activities with maximum value and goal value of each activity in accordance with the purpose of this paper. In Table IV shows the results of the goal programming process. For the value of *D2* indicates whether the objective value on the act will be subtracted or added to the maximum value.

V. RESULT AND DISCUSSION

In the previous section, an example has been calculated on the prepare tool activity. In this stage is to analyze the results that have been obtained from the overall calculation of each activity that existed in the events log. The result of maximum time comparison and goal time refer to Fig.4.

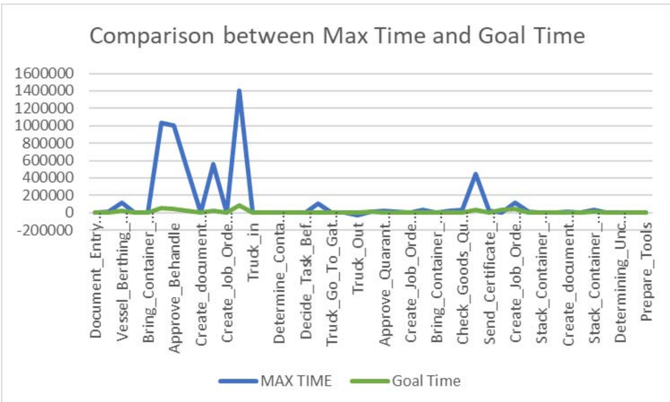


Fig.4. Comparison between Max Time and Goal Time

In fig.4 there are each activities that have a time value that is very far from the goal. In the activity "Send Job Order Delivery Info" has the highest difference to the goal value of time. This is because every activity on loading and unloading there is activity "Send Job Order Delivery Info" after doing activity "Create Job Order Document Delivery" and before activity "Truck In". For the value of the difference between max value time and the goal time on "Send Job Order Delivery Info" activity is 1323098 *h*, which comes from the maximum time = 1406832 *h* minus the goal time value = 83735 h.

This is 5 activities that have the highest difference value in fig 4. "Send Job Order Delivery Info", "Stack Container in Yard", "Approve Behandle", "Verification Document Behandle", "Create document KH / KT. To analyze each activity contained in the loading and unloading then conducted an analysis based on objective value using goal programming based on linear programming. In this process it used like as fig 2 and the result like as Fig.3. Where each activity has its own objective value. The result of objective value refers to fig.5.

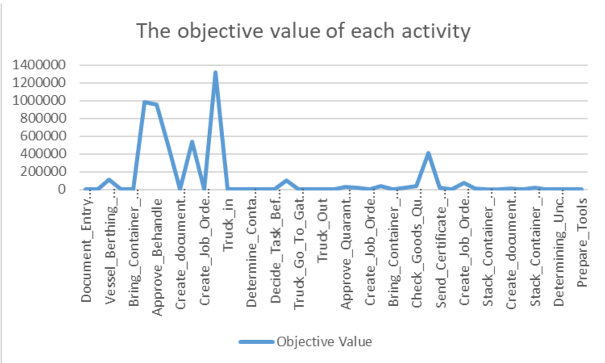


Fig.5. The objective value of each activity.

In fig.5 is the value of the goal programming result that produces the objective value of each activity. Objective value is derived from the amount of deviation of goal programming of each activities. Each activities shows change in *D12* and *D22* which indicates a negative result. If it produces a value on that variable then the objective value will be subtracted to the maximum value as described before. And if it shows the change in the variable *D11* and *D21* then the value on the variable will be added to the maximum value on the activity being done goal programming process. To find out how much activity changes in order to produce optimal results on the optimization of cost and time. In Table IV shows the results of the goal programming process.

From the result of goal programming process there are result of *D21* which have 24 negative result and 20 positive result. This shows that the need for time optimization of 24 activities that have negative results in order to achieve the targets specified. In this study target is used on average because research data based on the year 2016 that has not implemented government decisions that optimize the maximum loading and unloading for 3 days. To conduct research, we use the average as the target of the activity to be optimized and the maximum value used as the input value to obtain the optimal value. In Table III is the result of manual calculation by analyzing the maximum and average value of each activity to be in the optimization to find which activities need to be evaluated.

To find out how the difference between the goal of time with the results of GP. The result of Comparison between goal time and GP refers to Fig.6.

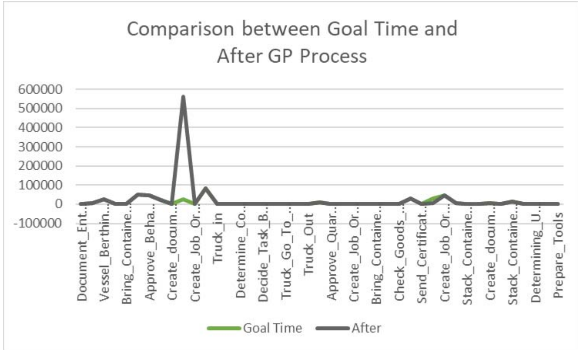


Fig.6. Comparison between Goal Time and GP

In fig.6 there are deviations on the ‘Create document SPPB’ and ‘Bring Container from Yard to Behandle’ activities because the objective value is greater than the maximum value then the activity is deviated. This is an aberration that occurs in loading and unloading activities. Due to the results obtained in the activity "Create document SPPB" is -44 h and "Bring Container from Yard to Behandle" activity is -44.17410797 h. For both activities have results that are beyond expectations. Which is where Goal Programming results in a reduction of the initial goal value. This needs to be further analyzed based on field performance on both activities. For overall results in accordance with the specified target as long as it can improve the performance on 24 activities with negative value. If the value is positive then it needs to be maintained or improved better. For that purpose, the evaluation of both activities.

VI. CONCLUSION

In this research, goal programming is used to optimize the time and cost for all activities in business process PCT. The main steps to calculate the time and cost optimization are looking for maximum value and average of cost and time each activity, Formulate a mathematical formulation for the next process, because goal programming is part of linear programming that can solve a solution using mathematical way, The mathematical formulation that has been created will be used as input on the lingo program. Lingo is the tools which we use to do the optimization. Based on the results in section x, there are deviations on the “Create_document_SPPB” and “Bring Container from Yard to Behandle” activities because the objective value is greater than the maximum value then the activity is deviated. For that purpose, the evaluation of both activities.

For future work, time and cost optimization using Goal programming will be applied to data with higher complexity and sample. The results of this study can be used as a reference for future research.

TABLE IV. RESULT EACH ACTIVITY OF GP IN PCT BUSINESS PROCESS

Activity	Time	OBJ	D2	Result GP
Document_Entry_via_PDE	31	34	-	89
Request_Behandle	3644	3647	-	7083
Vessel_Berthing_Process	91134	109719.41	+	27542
Discharge_Container	31.6123	34.6123	+	440.1944
Bring_Container_to_Yard	31	53.30683	+	149
Stack_Container_in_Yard	983987	983993.2354	-	51669.91556
Approve_Behandle	958168	958170.9328	-	45457.69296
Verification_Document_Behandle	476583	476586.2278	+	23868.66135
Create_document_SPPB	1086.856	1089.856	-	-44
Send_SPPB_Info	1	537511	-	563007.1221
Create_Job_Order_Document_Delivery	31	42.5373	-	148.9429154
Send_Job_Order_Delivery_Info	1323098	1323101	-	83734.24946
Truck_in	25	39.0286	+	78.83076791
Dispatch_WQ_Delivery_to_CHE	25	28.320759	+	163.9611199
Determine_Container_Type	24	28.022901	+	134.482397
Determining_Dry	11	19.01884	+	88.66024009
Decide_Task_Before_Lift_Container	613	615.102253	-	166.2972416
Lift_on_Container_Truck	102593	102598.5978	-	2730.855386
Truck_Go_To_Gate_Out	11	13.660727	-	88.6619676
Check_Container_before_Truck_out	11	15.152628	-	88.65479667
Truck_Out	1	4	-	1
……………………………………………	…………………..	………………	………………	………………
Prepare_Tools	8	26.46774	+	148.7077411

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REFERENCES

[1] J. E. Jarrett, "Throughput Port Demand Forecasting," *Int. J. Econ. Manag. Sci.*, vol. 4, no. 9, Oct. 2015.

[2] Y. A. Effendi and R. Sarno, "Non-Linear Optimization of Critical Path Method," *Accepted International Conference on Science in Information Technology (ICSITech)*, Oktober 2017. DOI: 10.1109/ICSITech.2017.8257091.

[3] U. C. Orumie and D. Ebong, "A Glorious Literature on Linear Goal Programming Algorithms," *Am. J. Oper. Res.*, vol. 04, no. 02, p. 59, Mar. 2014.

[4] Y. A. Effendi and R. Sarno, "Discovering optimized process model using rule discovery hybrid particle swarm optimization," 3rd International Conference on Science in Information Technology (ICSITech), pp. 97-103, 2017. DOI: 10.1109/ICSITech.2017.8257092

[5] Y. A. Effendi and R. Sarno, "Discovering process model from event logs by considering overlapping rules," 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI), pp. 1-6, 2017. DOI: 10.1109/EECSI.2017.8239193

[6] K. D. Febriyanti, R. Sarno, and Y. A. Effendi, "Fraud Detection on Event Log Using Fuzzy Association Rule Learning," International Conference On Information & Communication Technology And System (ICTS), pp.149-154, 2017. DOI: 10.1109/ICTS.2017.8265661

[7] R. Sarno and Y. A. Effendi, "Hierarchy Process Mining from Multi-Source Logs," Telecommunication, Computing, Electronics and Control (TELKOMNIKA), Vol.15, No.4, 2017
DOI: http://dx.doi.org/10.12928/telkomnika.v15i4.6326

[8] J. Prišenk, J. Turk, Č. Rozman, A. Borec, M. Zrakić, and K. Pažek, "Advantages of combining linear programming and weighted goal programming for agriculture application," *Oper. Res.*, vol. 14, no. 2, pp. 253–260, Jul. 2014.

[9] Z. Miao and W. Lin, "Based on Goal Programming Model of Optimization Study of Dyeing and Finishing Technology," in *2015 International Conference on Intelligent Transportation, Big Data and Smart City*, 2015, pp. 148–151.

[10] Y. A. Effendi and R. Sarno, "SWRL Rules for Identifying Short Loops in Business Process Ontology Model," International Conference On Information & Communication Technology And System (ICTS), PP.209-214, 2017. DOI: 10.1109/ICTS.2017.8265672

[11] S. Im, S. Li, B. Moseley, and E. Torng, "A Dynamic Programming Framework for Non-preemptive Scheduling Problems on Multiple Machines: Extended Abstract," in *Proceedings of the Twenty-sixth Annual ACM-SIAM Symposium on Discrete Algorithms*, Philadelphia, PA, USA, 2015, pp. 1070–1086.

[12] R. Jayaraman, C. Colapinto, D. La Torre, and T. Malik, "A Weighted Goal Programming model for planning sustainable development applied to Gulf Cooperation Council Countries," *Appl. Energy*, vol. 185, no. Part 2, pp. 1931–1939, Jan. 2017.

[13] L. Hakim, T. Bakhtiar, and Jaharuddin, "The nurse scheduling problem: a goal programming and nonlinear optimization approaches," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 166, no. 1, p. 012024, 2017.

[14] M. Labidi, M. Mrad, A. Gharbi, and M. A. Louly, "Scheduling IT Staff at a Bank: A Mathematical Programming Approach," *Sci. World J.*, vol. 2014, p. 10, 2014.