

Time and Cost Optimization using Fuzzy Goal Programming

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Abstract— In an industry that is often faced with the problem of optimizing compound goals to be achieved such as maximizing sales, maximizing total production, and production costs. Multi objective linear programming method can be applied effectively in production planning because it has a great chance to solve every different aspect of production planning. In this research, we will apply fuzzy goal programming method to optimize time and cost in Port Container Handling. The experimental results have been conducted using three variants with different cases provide match results the desired by the decision maker. From the three variants, the second variant provides the most optimal results compared to other variants.

Keywords—time and cost optimization; multi objective linear programming; fuzzy goal programming; port container handling

I. INTRODUCTION

Planning is an important stage in the decision-making process. Good planning will determine the success rate in the industry. In an industry often faced with the problem of optimizing compound goals to be achieved such as maximizing sales value, maximizing total production, and minimizing production costs without necessarily reducing product quality. These goals contain different aspects that often do not coexist with one another [1].

Several methods are used to solve problems by providing optimal results such as through non-linear optimization approach and linear optimization [2]. The method that considers several objectives in a linear programming model is called multi-objective linear programming (MOLP) [3]. The MOLP method can be applied effectively in production planning, as it is likely to solve every different aspect of production planning [4].

Some of the methods used to solve the problem of compound destination model are goal programming (GP) and fuzzy goal programming (FGP). In GP each objective is weighted prior to analysis, whereas in FGP each goal is not given discrete weight, but it is enough to consider the decision maker's desire to determine the value constraints on each function of the existing goal [5].

Based on research that has been done by Tampinongkol [4] where in the research aims to design an application to solve the problem of fuzzy goal programming and determination of

optimal solution result on company UD. Sinar Sakti Manado. The data used is the data of the company's production in 2014. In a study conducted by Effendi [6] where in this research aims to apply *non-linear* optimization method to *double timestamp event log*, the results of the study yielded an optimal solution of 71.83 hours and a cost of 2,853,415,853. Research conducted by Sutanto [7] where in the study aims to overcome obstacles when the shortage of goods at the retail level takes a long time in the distribution of goods from the warehouse to retailers. With the *physical internet* approach, the warehouse function and distribution center is replaced by a hub that serves to optimize transportation and availability. Research conducted by Sarno [8] aims to obtain minimum time duration and additional minimum cost of *single timestamp event log* using *linear programming*. Research conducted by Wiguna [9] aims to design a GIS application to map the location of a solar farm with a combination of methods between Fuzzy AHP and PROMETHEE.

In this research will be done cost optimization and dwelling time at Port Container Handling in Surabaya using Fuzzy Goal Programming. By using three different case variants, we will optimize the time and cost in each variant using the FGP method. The results from the FGP method in each variant will produce the most optimal variant.

II. RESEARCH METHODOLOGY

A. FCFS

First Come First Served (FCFS) is a scheduling algorithm where every ready-made process will be included in FIFO queue with first in first out principle, according to the time of arrival. The first process arrives to be executed.

FCFS formulated as follows:

$$TA = WT + LE \quad (1)$$

$$\overline{TA} = \sum TA / \sum J \quad (2)$$

$$WT = ME - WK \quad (3)$$

Where,

TA : Turn around

LE : Length of execution

J : Job

WT : Waiting time

ME : Start the execution

LS : Time of arrival

B. Fuzzy Goal Programming

Fuzzy goal programming is a fuzzy programming approach to goal programming, where this method does not need to perform weighting calibration or do selection to the degree of importance of purpose function. This method only uses special preferences on the objectives that can be modeled by using the fuzzy membership function [10].

The FGP method is formulated as follows:

If $x = [x_1, x_2, \dots, x_n]^T \in \mathcal{R}^n$ as a vector decision variables $f(x) = (f_1(x), \dots, f_m(x))$ is an objective function with constraint system form $G(x)$. Decision-makers want limits $f_i^*, (i = 1, 2, \dots, m)$ for each purpose function that meets the linear constraints $G(x)$. Using the concept of fuzzy sets, membership functions can be defined as follows:

$$1) \text{ State } \text{Max} f_i(x), i = 1, 2, \dots, m \quad (4)$$

With constraint $x \in G(x) \in \mathcal{R}^n$

Suppose obtained $x_j^* (j = 1, 2, \dots, n)$ is an optimal solution at objective function $f_i(x)$, get $f_i(x_j^*) = f_{i \max}$

$$2) \text{ Find } \min f_i(x_j^*) = f_{i \min} \text{ for each } i.$$

3) Define membership function $\mu_{f_i}(x), (1, 2, \dots, m)$ in the form of:

$$\mu_{f_i}(x) = \begin{cases} \frac{f_{i \max} - f_i(x)}{f_{i \max} - f_i^*} & f_i^* < f_i(x) \leq f_{i \max} \\ 1 & f_i(x) = f_i^* \\ \frac{f_i(x) - f_{i \max}}{f_i^* - f_{i \min}} & f_{i \min} \leq f_i(x) < f_i^* \end{cases}$$

4) Next define λ - level $F_i^\lambda(x)$ or $F(\lambda, x)$ so formed FGP model that is:

Define x^* , that meet:

$$\text{Max } \lambda \quad (5)$$

$$\text{With constraint } x \in F(\lambda, x) \cap G(x)$$

$$F(\lambda, x) = F^\lambda(x) = F_1^\lambda(x) \cap F_2^\lambda(x) \cap \dots \cap F_i^\lambda(x) \dots \cap F_m^\lambda(x)$$

$$\text{With } F_i^\lambda(x) = \{x | \mu_{f_i}(x) \geq \lambda; 0 \leq \lambda \leq 1, x \in F_i(x)\}$$

Since the purpose function in the model to be discussed is the problem of maximization and minimization, according to Singh, FGP can be expressed:

$$\text{Define } x \quad (6)$$

Until,

$$F_i(x) \leq f_i \text{ or } F_i(x) \geq f_i (1, 2, \dots, m)$$

With constraint,

$$Ax \leq b, x \geq 0$$

Where $F_i(x)$ is a objective to i , f_i is a level aspiration of purpose function $F_i(x)$, A is a matrix coefficient of use of each

resource to produce a unit of decision variable value x_j , and b is a vector column on the right side of the constraint that states the availability of each resource.

The membership function $\mu_{f_i}(x)$ for each objectives fuzzy can be expressed in form:

$$1) \text{ If } F_i(x) \leq f_i, \text{ so that } \mu_{f_i}(x) = \begin{cases} 1 & F_i(x) \leq f_i \\ \frac{U_i - F_i(x)}{U_i - f_i} & f_i \leq F_i(x) \leq U_i \\ 0 & F_i(x) \geq U_i \end{cases} \quad (7)$$

$$2) \text{ If } F_i(x) \geq f_i, \text{ so that } \mu_{f_i}(x) = \begin{cases} 1 & F_i(x) \geq f_i \\ \frac{F_i(x) - L_i}{f_i - L_i} & L_i \leq F_i(x) \leq f_i \\ 0 & F_i(x) \leq L_i \end{cases} \quad (8)$$

Where U_i and L_i is the upper and lower limits of the desired decision maker's preferences f_i is an optimal limits (*max* or *min*) from the model.

Model FGP (2) and (3) can be expressed in form:

Define x^* that meet,

$$\text{Max } \lambda \quad (9)$$

With constraint,

$$\mu_{f_i}(x) \geq \lambda$$

$$Ax \leq b, x \geq 0$$

Next the membership fuzzy function in purpose function is:

$$\mu_{f_i}(x) = \begin{cases} 1 & F_i(x) \leq f_{i \min} \\ \frac{U_i - F_i(x)}{U_i - f_{i \min}} & f_{i \min} \leq F_i(x) \leq U_i \\ 0 & F_i(x) \geq U_i \end{cases} \quad (10)$$

$$\mu_{f_i}(x) = \begin{cases} 1 & F_i(x) \geq f_{i \max} \\ \frac{F_i(x) - L_i}{f_{i \max} - L_i} & L_i \leq F_i(x) \leq f_{i \max} \\ 0 & F_i(x) \leq L_i \end{cases} \quad (11)$$

The form about membership function (7) and (8) can showing in Fig. 1:

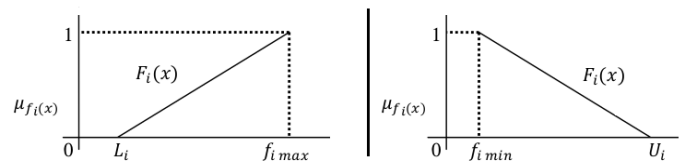


Fig. 1. The Form Membership Fuzzy Function

The greater the value λ which is obtained, will result in the fuzzy membership value for each purpose function will be greater which means the solution obtained close to the optimal value (*max* or *min*).

III. RESULT & ANALYSIS

The results and discussion of the experiments that have been conducted, described as follows:

A. Data Testing

The data used is dwelling time of log data at Port Container Handling in Surabaya (TPS). The data used are 3 variants, with different cases in each variant, data for all three variants are shown in Table 1, Table II, and Table III. Table I shows data variants 1 which will be used in this research, meanwhile data variants 2 and data variants 3 are explained in Table II and Table III respectively.

TABLE I. DATA VARIANTS 1

Activity	Cost	Time
DocumentEntryviaPDE	0	1
RequestBehandle	0	148
VesselBerthingProcess	53203.499	450
DischargeContainer	497.36707	22
BringContainertoYard	60.465331	2
StackContainerinYard	23.567584	855
ApproveBehandle	1.8458175	828
VerificationDocumentBehandle	6.7904388	413
CreatedocumentSPPB	2659.4633	0
SendSPPBInfo	0	464
CreateJobOrderDocumentDelivery	35.226131	2
SendJobOrderDeliveryInfo	0	1227
Truckin	11.701589	1
DispatchWQDeliverytoCHE	1.0388558	2
DetermineContainerType	2.3353664	2
DeterminingDry	18.383139	1
DecideTaskBeforeLiftContainer	2.3349725	2
LiftonContainerTruck	19.326058	39
TruckGoToGateOut	2.3282795	1
CheckContainerbeforeTruckout	2.3293147	1
TruckOut	11.696781	0

TABLE II. DATA VARIANTS 2

Activity	Cost	Time
DocumentEntryviaPDE	0	1
RequestBehandle	0	146
VesselBerthingProcess	64278.76	249
DischargeContainer	609.39495	27
BringContainertoYard	68.269487	2
StackContainerinYard	24.041282	749
ApproveBehandle	1.827298	726
VerificationDocumentBehandle	7.0275265	362
CreatedocumentSPPB	2668.252	0

Activity	Cost	Time
SendSPPBInfo	0	407
CreateJobOrderDocumentDelivery	22.471991	2
SendJobOrderDeliveryInfo	0	526
Truckin	7.8268536	1
DispatchWQDeliverytoCHE	0.6447958	2
DetermineContainerType	1.4776138	2
DeterminingRefeer	18.97	1
DecideTaskBeforeLiftContainer	1.5330109	7
UnplugRefeerCable	7.3126053	2
LiftonContainerTruck	19.872564	51
TruckGoToGateOut	1.4389431	1
CheckContainerbeforeTruckout	1.4886588	1
TruckOut	7.4535667	0

TABLE III. DATA VARIANTS 3

Activity	Cost	Time
DocumentEntryviaPDE	0	1
RequestBehandle	0	144
VesselBerthingProcess	86387.533	525
DischargeContainer	752.0524	39
BringContainertoYard	219.36	2
StackContainerinYard	0	457
ApproveBehandle	1.667465	442
VerificationDocumentBehandle	6.3342884	220
CreatedocumentSPPB	2616.4689	0
SendSPPBInfo	0	248
CreateJobOrderDocumentDelivery	37.533098	2
SendJobOrderDeliveryInfo	0	274
Truckin	13.7574	1
DispatchWQDeliverytoCHE	1.1709138	2
DetermineContainerType	2.5295104	2
DeterminingUncontainer	14.79	1
DecideTaskBeforeLiftContainer	2.5724404	12
PrepareTools	77.828162	2
LiftonContainerTruck	47.94	64
TruckGoToGateOut	2.7060354	1
CheckContainerbeforeTruckout	3.0465592	1
TruckOut	13.555816	0

B. Proposed Method

Steps of research that will be done, showing in Fig. 2:

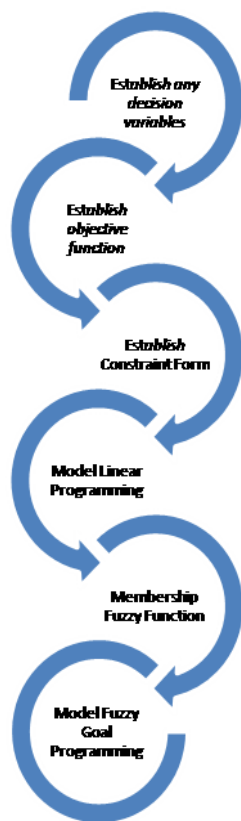


Fig. 2. The proposed method

1) *Establish any decision variables* is all activities undertaken at Port Container Handling in Surabaya for each variant:

Variant 1:

$x_1 = DocumentEntryviaPDE$
 $x_2 = RequestBehandle$
 $x_3 = VesselBerthingProcess$
 $x_4 = DischargeContainer$
 $x_5 = BringContainertoYard$
 $x_6 = StackContainerinYard$
 $x_7 = ApproveBehandle$
 $x_8 = VerificationDocumentBehandle$
 $x_9 = CreatedocumentSPPB$
 $x_{10} = SendSPPBInfo$
 $x_{11} = CreateJobOrderDocumentDelivery$
 $x_{12} = SendJobOrderDeliveryInfo$
 $x_{13} = Truckin$
 $x_{14} = DispatchWQDeliverytoCHE$
 $x_{15} = DetermineContainerType$
 $x_{16} = DeterminingDry$
 $x_{17} = DecideTaskBeforeLiftContainer$
 $x_{18} = LiftonContainerTruck$
 $x_{19} = TruckGoToGateOut$
 $x_{20} = CheckContainerbeforeTruckout$

$x_{21} = TruckOut$

Variant 2:

$x_1 = DocumentEntryviaPDE$
 $x_2 = RequestBehandle$
 $x_3 = VesselBerthingProcess$
 $x_4 = DischargeContainer$
 $x_5 = BringContainertoYard$
 $x_6 = StackContainerinYard$
 $x_7 = ApproveBehandle$
 $x_8 = VerificationDocumentBehandle$
 $x_9 = CreatedocumentSPPB$
 $x_{10} = SendSPPBInfo$
 $x_{11} = CreateJobOrderDocumentDelivery$
 $x_{12} = SendJobOrderDeliveryInfo$
 $x_{13} = Truckin$
 $x_{14} = DispatchWQDeliverytoCHE$
 $x_{15} = DetermineContainerType$
 $x_{16} = DeterminingRefeer$
 $x_{17} = DecideTaskBeforeLiftContainer$
 $x_{18} = UnplugRefeerCable$
 $x_{19} = LiftonContainerTruck$
 $x_{20} = TruckGoToGateOut$
 $x_{21} = CheckContainerbeforeTruckout$
 $x_{22} = TruckOut$

Variant 3:

$x_1 = DocumentEntryviaPDE$
 $x_2 = RequestBehandle$
 $x_3 = VesselBerthingProcess$
 $x_4 = DischargeContainer$
 $x_5 = BringContainertoYard$
 $x_6 = StackContainerinYard$
 $x_7 = ApproveBehandle$
 $x_8 = VerificationDocumentBehandle$
 $x_9 = CreatedocumentSPPB$
 $x_{10} = SendSPPBInfo$
 $x_{11} = CreateJobOrderDocumentDelivery$
 $x_{12} = SendJobOrderDeliveryInfo$
 $x_{13} = Truckin$
 $x_{14} = DispatchWQDeliverytoCHE$
 $x_{15} = DetermineContainerType$
 $x_{16} = DeterminingUncontainer$
 $x_{17} = DecideTaskBeforeLiftContainer$
 $x_{18} = PrepareTools$
 $x_{19} = LiftonContainerTruck$
 $x_{20} = TruckGoToGateOut$
 $x_{21} = CheckContainerbeforeTruckout$
 $x_{22} = TruckOut$

2) The objective function to be achieved by the company is to minimize symbolic cost $Z(x)$.

for variant 1:

$$\text{Min } Z(x) = 0x_1 + 0x_2 + 53203,5x_3 + \dots + 11,7x_{21}$$

for variant 2:

$Min Z(x) = 0x_1 + 0x_2 + 64278,8x_3 + \dots + 18,9x_{22}$
 for variant 3:
 $Min Z(x) = 0x_1 + 0x_2 + 86387,5x_3 + \dots + 13,5x_{22}$
 and for the second purpose is to minimize the time symbolized by $H(x)$.
 for variant 1:
 $Min H(x) = 1x_1 + 148x_2 + 150x_3 + \dots + 0x_{21}$
 for variant 2:
 $Min H(x) = 1x_1 + 146x_2 + 249x_3 + \dots + 0x_{22}$
 for variant 3:
 $Min H(x) = 1x_1 + 144x_2 + 525x_3 + \dots + 0x_{22}$

3) Establish any form of constraint that is the company's desire to process dwelling time for three days with the most optimal cost.
 for variant 1:
 $Dwelling Time = 1x_1 + 148x_2 + \dots + 0x_{21} \leq 7143$
 for variant 2:
 $Dwelling Time = 1x_1 + 146x_2 + \dots + 0x_{22} \leq 7143$
 for variant 3:
 $Dwelling Time = 1x_1 + 144x_2 + \dots + 0x_{22} \leq 7143$

4) Model linear programming to minimize costs and time, can be expressed as follows:
 The objective function:

for variant 1:
 $Min Z(x) = 0x_1 + 0x_2 + 53203,5x_3 + \dots + 11,7x_{21}$
 $Min H(x) = 1x_1 + 148x_2 + 150x_3 + \dots + 0x_{21}$
 for variant 2:
 $Min Z(x) = 0x_1 + 0x_2 + 64278,8x_3 + \dots + 18,9x_{22}$
 $Min H(x) = 1x_1 + 146x_2 + 249x_3 + \dots + 0x_{22}$
 for variant 3:
 $Min Z(x) = 0x_1 + 0x_2 + 86387,5x_3 + \dots + 13,5x_{22}$
 $Min H(x) = 1x_1 + 144x_2 + 525x_3 + \dots + 0x_{22}$

Forms constraints:
 for variant 1:
 $Dwelling Time = 1x_1 + 148x_2 + \dots + 0x_{21} \leq 7143$
 for variant 2:
 $Dwelling Time = 1x_1 + 146x_2 + \dots + 0x_{22} \leq 7143$
 for variant 3:
 $Dwelling Time = 1x_1 + 144x_2 + \dots + 0x_{22} \leq 7143$

5) The Fuzzy membership function is formed based on the optimal solution obtained from the calculation of linear programming and decision maker preference. The fuzzy membership function for the minimum cost purpose is:

$$\mu_{Z(x)} = \begin{cases} 1 & Z(x) \leq Z^* \\ \frac{\bar{Z} - Z(x)}{\bar{Z} - Z^*} & Z^* \leq Z(x) \leq \bar{Z} \\ 0 & Z(x) \geq \bar{Z} \end{cases}$$

The function of fuzzy membership for the minimum purpose of time is:

$$\mu_{H(x)} = \begin{cases} 1 & H(x) \leq H^* \\ \frac{\bar{H} - H(x)}{\bar{H} - H^*} & H^* \leq H(x) \leq \bar{H} \\ 0 & H(x) \geq \bar{H} \end{cases}$$

Where,
 Z^* : Minimum cost solution for linear programming.
 \bar{Z} : The maximum cost the decision owner wants.
 H^* : Minimum time solution for linear programming.
 \bar{H} : The maximum time the decision owner wants.

6) Model fuzzy goal programming, after the solution is determined from each destination which is expressed in the fuzzy membership function. This model will be modeled with one purpose that can be analyzed such as linear programming model. For $\mu_{Z(x)} \geq \lambda$ with $\mu_{Z(x)} = \frac{\bar{Z} - Z(x)}{\bar{Z} - Z^*}$ at $Z^* \leq Z(x) \leq \bar{Z}$, at \bar{Z} and Z^* the valuable real, apply $Z(x) + (\bar{Z} - Z^*)\lambda \leq \bar{Z}$
 $a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n + (\bar{Z} - Z^*)\lambda \leq \bar{Z}$
 For $\mu_{H(x)} \geq \lambda$ with $\mu_{H(x)} = \frac{\bar{H} - H(x)}{\bar{H} - H^*}$ at $H^* \leq H(x) \leq \bar{H}$, where \bar{H} and H^* the valuable real, apply $H(x) + (\bar{H} - H^*)\lambda \leq \bar{H}$
 $b_{11}x_1 + b_{12}x_2 + \dots + b_{1n}x_n + (\bar{H} - H^*)\lambda \leq \bar{H}$
 Then the fuzzy goal programming model obtained is:
 Max λ

With constraints:
 for variant 1:
 $0x_1 + 0x_2 + \dots + 11,7x_{21} + (84624,84624)\lambda \leq 84624$
 $1x_1 + 148x_2 + 150x_3 + \dots + 0x_{21} + (7143,2827)\lambda \leq 7143$
 $1x_1 + 148x_2 + \dots + 0x_{21} \leq 7143$
 for variant 2:
 $0x_1 + 0x_2 + \dots + 18,9x_{22} + (84624,84624)\lambda \leq 84624$
 $1x_1 + 146x_2 + 249x_3 + \dots + 0x_{22} + (7143,956)\lambda \leq 7143$
 $1x_1 + 146x_2 + \dots + 0x_{22} \leq 7143$
 for variant 3:
 $0x_1 + 0x_2 + \dots + 13,5x_{22} + (84624,79048)\lambda \leq 84624$
 $1x_1 + 146x_2 + 525x_3 + \dots + 0x_{22} + (7143,1555)\lambda \leq 7143$
 $1x_1 + 144x_2 + \dots + 0x_{22} \leq 7143$

The results of experiments performed using fuzzy programming objectives gave results on Variant 1 at a cost of US\$84624, time 2827 minutes. Variant 2 is US\$84624 cost, 956 minutes time. Variant 3 is US\$79048 for cost, while 1555 minutes time. The results of time optimization on each variant obtained with fuzzy goal programming are shown in Fig. 3. While the optimization cost is seen in Fig. 4.

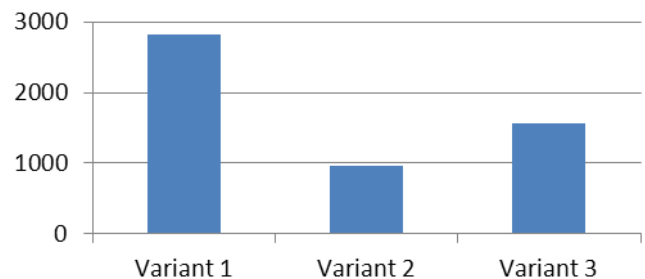


Fig. 3. Optimization Results in Time of Three Variants

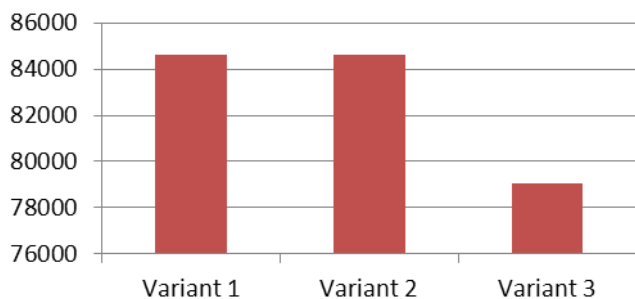


Fig. 4. Optimization Results in Cost of Three Variants

IV. CONCLUSION

Cost and time optimization performed on fuzzy goal programming method give optimization result of cost for Variants 1 remain the same as US\$84624 from the desire of the decision maker equal to US\$84624. While the optimization time for Variants 1 of 2827 minutes from the decision of the owner of decision 7143 minutes, while for the optimization of cost for Variants 2 of US\$84624 and time 956 minutes, and cost optimization results for Variants 3 of US\$79048 and time 1555 minutes. From the results of tests conducted Variants 3 provides more optimal results compared with other variants. In the next research, the fuzzy goal programming method will be applied to data with higher complexity and sample by applying another variation of the fuzzy method.

V. ACKNOWLEDGMENT

We are very grateful to all those who helped this research so that it went smoothly from start to finish, in particular Port Container Handling in Surabaya which has provided datasets for this research and also to Department of Informatics, Institut Teknologi Sepuluh Nopember.

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