Time and Cost Optimization using Fuzzy Goal Programming

Made Agus Putra Subali, Riyanto Sarno, Yutika Amelia Effendi
Department of Informatics
Faculty of Information and Communication Technology, Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
Email: madeagusputrasubali@gmail.com, riyanto@if.its.ac.id, yutika.effendi@gmail.com

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 faces 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:

\[
TA = WT + LE
\]

\[
\overline{TA} = \frac{\sum TA}{\sum j}
\]

\[
WT = ME - WK
\]

Where,

\(TA\) : Turn around

\(LE\) : Length of execution

\(j\) : Job
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 \( x = [x_1, x_2, \ldots, x_n]^T \in \mathbb{R}^n \) as a vector decision variables \( f(x) = (f_1(x), \ldots, f_m(x)) \) is an objective function with constraint system form \( G(x) \). Decision-makers want limits \( f_i^*(i = 1, 2, \ldots, m) \) 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) State
   \[
   \begin{align*}
   \text{Max} & \ f_i(x), \ i = 1, 2, \ldots, m \\
   \text{With constraint} & \ x \in G(x) \in \mathbb{R}^n \\
   \text{Suppose obtained} & \ x_j^* (j = 1, 2, \ldots, n) \text{is an optimal solution} \\
   \text{at objective function} & \ f_i(x), \text{get} \ f_i(x_j^*) = f_{i, \text{max}} \\
   \end{align*}
   \]

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

3) Define membership function \( \mu_{f_i}(x), (1, 2, \ldots, m) \) in the form of:
   \[
   \begin{align*}
   & \mu_{f_1}(x) = \begin{cases} 
   \frac{f_{i, \text{max}} - f_i(x)}{f_{i, \text{max}} - f_{i, \text{min}}} & f_i(x) = f_{i, \text{min}} \\
   1 & f_i(x) \leq f_i^* \\
   \frac{f_i(x) - f_{i, \text{max}}}{f_{i, \text{max}} - f_{i, \text{min}}} & f_i(x) \leq f_{i, \text{min}} \\
   \end{cases} \\
   
   \end{align*}
   \]

4) Next define \( \lambda - \text{level of} F_i^\lambda(x) \) or \( F(\lambda,x) \) so formed FGP model that is:
   Define \( x^* \), that meet:
   \[
   \begin{align*}
   \text{Max} & \ \lambda \\
   \text{With constraint} & \ x \in \mathcal{F}(\lambda,x) \cap \mathcal{G}(x) \\
   \text{F}(\lambda,x) & = F^\lambda(x) = F_i^\lambda(x) \cap \cdots \cap F_m^\lambda(x) \\
   \text{With} \ F_i^\lambda(x) & = \{ x | \mu_{f_i}(x) \geq \lambda : 0 \leq \lambda \leq 1, x \in \mathcal{F}(x) \} \\
   \end{align*}
   \]

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

Define \( x \)
   \[
   \begin{align*}
   \text{Max} & \ F_i(x), \ i = 1, 2, \ldots, m \\
   \text{With constraint} & \ A x \leq b, x \geq 0 \\
   \text{Where} & \ F_i(x) \text{ is a objective to} \ i, f_i \text{ is a level aspiration of purpose function} \ F_i(x) \\
   \end{align*}
   \]

The greater the value \( \lambda \) 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.

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</table>
**B. Proposed Method**

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

![Diagram showing steps of research](image)

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

**Variant 1:**
- \( x_1 = \text{DocumentEntryviaPDE} \)
- \( x_2 = \text{RequestBehandle} \)
- \( x_3 = \text{VesselBerthingProcess} \)
- \( x_4 = \text{DischargeContainer} \)
- \( x_5 = \text{BringContaineritoYard} \)
- \( x_6 = \text{StackContainerinYard} \)
- \( x_7 = \text{ApproveBehandle} \)
- \( x_8 = \text{VerificationDocumentBehandle} \)
- \( x_9 = \text{CreatedocumentSPPB} \)
- \( x_{10} = \text{SendSPPBInfo} \)
- \( x_{11} = \text{CreateJobOrderDocumentDelivery} \)
- \( x_{12} = \text{SendJobOrderDeliveryInfo} \)
- \( x_{13} = \text{Truckin} \)
- \( x_{14} = \text{DispatchWQDeliverytoCHE} \)
- \( x_{15} = \text{DetermineContainerType} \)
- \( x_{16} = \text{DeterminingRefeer} \)
- \( x_{17} = \text{DecideTaskBeforeLiftContainer} \)
- \( x_{18} = \text{UnplugRefeerCable} \)
- \( x_{19} = \text{LiftonContainerTruck} \)
- \( x_{20} = \text{TruckGoToGateOut} \)
- \( x_{21} = \text{TruckOut} \)

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

For variant 1:
\[
\text{Min } Z(x) = 0x_1 + 0x_2 + 53203.5x_3 + \cdots + 11.7x_{21}
\]

For variant 2:
Min Z(x) = 0x₁ + 0x₂ + 64278.8x₃ + ... + 18.9x₂₂
for variant 3:
Min Z(x) = 0x₁ + 0x₂ + 86387.5x₃ + ... + 13.5x₂₂
and for the second purpose is to minimize the time symbolized by H(x).

for variant 1:
Min H(x) = 1x₁ + 148x₂ + 150x₃ + ... + 0x₂₁
for variant 2:
Min H(x) = 1x₁ + 146x₂ + 249x₃ + ... + 0x₂₂
for variant 3:
Min H(x) = 1x₁ + 144x₂ + 525x₃ + ... + 0x₂₂

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 = 1x₁ + 148x₂ + ... + 0x₂₁ ≤ 7143
for variant 2:
Dwelling Time = 1x₁ + 146x₂ + ... + 0x₂₂ ≤ 7143
for variant 3:
Dwelling Time = 1x₁ + 144x₂ + ... + 0x₂₂ ≤ 7143

4) Model linear programming to minimize costs and time, can be expressed as follows:
The objective function:
for variant 1:
Min Z(x) = 0x₁ + 0x₂ + 53203,5x₃ + ... + 11.7x₂₁
Min H(x) = 1x₁ + 148x₂ + 150x₃ + ... + 0x₂₁
for variant 2:
Min Z(x) = 0x₁ + 0x₂ + 64278.8x₃ + ... + 18.9x₂₂
Min H(x) = 1x₁ + 146x₂ + 249x₃ + ... + 0x₂₂
for variant 3:
Min Z(x) = 0x₁ + 0x₂ + 86387.5x₃ + ... + 13.5x₂₂
Min H(x) = 1x₁ + 144x₂ + 525x₃ + ... + 0x₂₂

Forms constraints:
for variant 1:
Dwelling Time = 1x₁ + 148x₂ + ... + 0x₂₁ ≤ 7143
for variant 2:
Dwelling Time = 1x₁ + 146x₂ + ... + 0x₂₂ ≤ 7143
for variant 3:
Dwelling Time = 1x₁ + 144x₂ + ... + 0x₂₂ ≤ 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:

\[ \mu_{Z(x)} = \begin{cases} 1 & \text{if } Z(x) \leq Z^* \\ \frac{Z - Z(x)}{Z - Z^*} & \text{if } Z(x) \leq Z^* \\ 0 & \text{if } Z(x) \geq Z \end{cases} \]

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

\[ \mu_{H(x)} = \begin{cases} 1 & \text{if } H(x) \leq H^* \\ \frac{H - H(x)}{H - H^*} & \text{if } H(x) \leq H^* \\ 0 & \text{if } H(x) \geq H \end{cases} \]

Where,

\( Z^- \) : Minimum cost solution for linear programming.
\( Z^+ \) : The maximum cost the decision owner wants.
\( H^- \) : Minimum time solution for linear programming.
\( H^+ \) : 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 \( \mu_{Z(x)} = \frac{Z - Z(x)}{Z^* - Z(x)} \) at \( Z^* \leq Z(x) \leq \bar{Z} \) and \( Z^* \) the valuable real, apply \( Z(x) + (\bar{Z} - Z^*)\lambda \leq \bar{Z} \)

For \( \mu_{H(x)} \geq \lambda \) with \( \mu_{H(x)} = \frac{H - H(x)}{H^* - H(x)} \) at \( H^* \leq H(x) \leq \bar{H} \), and \( H^* \) the valuable real, apply \( H(x) + (\bar{H} - H^*)\lambda \leq \bar{H} \)

Then the fuzzy goal programming model obtained is:

\[ \text{Max } \lambda \]

With constraints:
for variant 1:
\[ 0x₁ + 0x₂ + ... + 11.7x₂₁ + (84624.84624)\lambda \leq 84624 \]
\[ 1x₁ + 148x₂ + 150x₃ + ... + 0x₂₁ + (7143.2827)\lambda \leq 7143 \]
\[ 1x₁ + 148x₂ + ... + 0x₂₁ \leq 7143 \]
for variant 2:
\[ 0x₁ + 0x₂ + ... + 18.9x₂₂ + (84624.84624)\lambda \leq 84624 \]
\[ 1x₁ + 146x₂ + 249x₃ + ... + 0x₂₂ + (7143.956)\lambda \leq 7143 \]
\[ 1x₁ + 146x₂ + ... + 0x₂₂ \leq 7143 \]
for variant 3:
\[ 0x₁ + 0x₂ + ... + 13.5x₂₃ + (84624.79048)\lambda \leq 84624 \]
\[ 1x₁ + 144x₂ + 525x₃ + ... + 0x₂₃ + (7143.1555)\lambda \leq 7143 \]
\[ 1x₁ + 144x₂ + ... + 0x₂₃ \leq 7143 \]

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

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REFERENCES