*ESTEEM Academic Journal*
Vol. 18, March 2022, 20-35

# The Application of DEA-ZOGP for the Optimization of Supplier Selection

Nur Rasyida Mohd Rashid[1], Bushra Abdul Halim[2], Wan Rosmanira Ismail[3], Iman Nabila Ahmad Sabri[4], Nur Effatin Natasya Mohd Erffa[5] and Siti Nor Liyana Azmi[6]
[1,4,5,6]*Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Negeri Sembilan, Seremban Campus, 73000, Seremban, Negeri Sembilan, Malaysia*
[2]*Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Melaka, Alor Gajah Campus, 78000, Alor Gajah, Melaka, Malaysia*
[3]*School of Mathematical Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
**corresponding author: [1]syida@uitm.edu.my*

**ARTICLE HISTORY**

Received
*5 January 2022*

Accepted
*9 March 2022*

Available online
*25 March 2022*

**ABSTRACT**

*The supplier selection process is gaining more attention in the production industry. Selecting the right supplier is an essential issue in business as well as supply chain systems since most of the companies work with several suppliers. A company needs to choose the best supplier based on qualitative and quantitative aspects where choosing the right supplier is also perceived as a decision-making process that requires multiple objectives to be achieved. In this study, the Data Envelopment Analysis (DEA) and Zero One Goal Programming method (ZOGP) methods are applied to choose the best supplier for a food manufacturing company in terms of qualitative and quantitative measurement. The input for the DEA model is the raw materials price while the outputs criteria are delivery time, shipping amount and response in quality problems. Every supplier is given a rating by the company based on those output criteria through Likert Scale from 1-10. In contrast, the ZOGP method considers quantitative constraints such as demand, purchasing cost, supply delay time, delivery time and percentages of discount of the raw materials. The mathematical modelling in this study is being executed using LINGO software. Finally, this research determined the best suppliers where both methods showed consistent results. This indicates the feasibility of utilizing the DEA in assessing the efficiency of the suppliers as well as ZOGP for the optimization of supplier selection problems which involves multiple criteria and objectives.*

**Keywords:** *Data Envelopment Analysis; Efficiency Score; Supplier Selection; Zero-One Goal Programming*

## 1. INTRODUCTION

The food industry has become the most promising and fast-growing industry throughout the world which also involves countries like Malaysia. One of the strategies to be competitive and sustainable in the industry is to have good supply chain management in terms of the raw materials procurement. Since raw material procurement is one of the initial processes in the industry, it is important to pay attention to the process of the supplier selection [1]. Generally, supplier selection is a process of choosing the right supplier, by which the company identifies, evaluates and selects the right suppliers based on several tangible and intangible criteria. Suppliers that can provide the customer with the exact number of products at the right time, in the right quality and with the best range of price are some of the main criteria of the selection

p-ISSN 1675-7939; e-ISSN 2289-934

process [2]. However, once the company has made an improper decision in selecting the supplier, it may be led to suffer losses and directly drag down the company's performances [3]. The effectiveness of the supplier selection process depends on how precisely the decision-makers evaluate the suppliers where each company has their own criteria in the selection process which depends on the goals they essentially need to achieve.

The performance evaluation of suppliers primarily emphasizes the product cost, product quality, delivery time and past performances of suppliers [4]. Therefore, the appropriate supplier selection is regarded as a multiple-criteria decision making (MCDM) process, which aims to evaluate several numbers of suppliers with a set of common criteria which includes qualitative and quantitative aspects [5]. There are many MCDM methods that have been proposed for solving supplier selection problems such as analytic hierarchy process, analytic network process, genetic algorithm, mathematical programming and fuzzy set theory [6]. Another method which is Data Envelopment Analysis (DEA) has become powerful in measuring the efficiency of a set of comparable entities known as decision making units (DMUs) [7].

## 2. LITERATURE REVIEW

Supplier selection has become one of the most important processes in the supply chain management in order to ensure high quality of product procurement as well as gaining the customers satisfaction. Measuring the performance of the supplier could be difficult as it involves multiple qualitative as well as quantitative aspects to be evaluated [8].

DEA, which is a nonparametric mathematical programming framework, is also a leading tool for performance analysis since it offers a better way of organizing and analyzing data [7]. The goal of this method is to determine the technical efficacy of all DMUs in the observation. DEA is also a performance evaluation and benchmarking methodology incorporating a variety of performance metrics [9]. The Decision-Making Units (DMUs) consider two groups of factors which are input and output that provide the efficiency score for each of the DMU with the range between 0 to 1 together with the potential decrease and increase of inputs and outputs to DMUs [10]. The less productive units or inefficiency are identified with an efficiency score that is less than 1. The CCR is the Constant Scale Returns (CRS) radial model where the CCR model can be categorized into two models which are input-oriented CCR model and output-oriented CCR model. Input-oriented CCR model is aimed to minimize the inputs used by maintaining the output produced while output-oriented CCR model focused on maximizing output produced by maintaining the input used [11].This method is also able to handle multiple inputs and outputs which are measured in different units. Hence, the application for efficiency measurement of problems with many DMUs has intensively been applied across a wide range of industries such as measuring the efficiency of water providers [12], banking [13], agriculture [14], portfolio selection [15] , sports [16] and education [17].

On the other hand, goal programming (GP) is a mathematical model which has the capability of handling multiple objectives of optimizations [18]. Consequently, rather than optimization, a satisfactory standard also can be obtained which leads to the concept of goals. In GP, each of the objectives is allocated at a target level for an achievement and pre-specified priority for the decision-maker to achieve the target [19]. The weight assigned in GP formulation has been used to quantify the importance of each goal with respect to the other goal. Zero-One Goal

p-ISSN 1675-7939; e-ISSN 2289-934

Programming (ZOGP) is one of the types in GP methodologies where the optimal decision variables can only be resulted as the value of one or zero [20]. The model has been applied often as it is simple to be used and easy to be comprehended by the decision-maker. Furthermore, ZOGP is used to determine the optimal values of a set of variables in problems that have different objectives. This method has also been applied widely in many areas such as in staff scheduling problems [20] and lecturer teaching scheduling [21], evacuation for disaster relief [22], asset and liability management [23], managerial strategic decision making [24] and balance sheet for banks [25].

Thus, the purpose of this study is to find the best supplier for a company through efficiency assessment of qualitative criteria by implementing the DEA model. Then, the decision on selecting the best supplier through quantitative measurement will be executed through the ZOGP model. The consistency of the results will be determined in the final stage in order to choose the best supplier for the company.

## 3. METHODOLOGY

### *3.1 Model Development*

The conceptual framework of this study is presented in Figure 1. The flow starts with data acquisition and then the efficiency of the supplier in terms of qualitative criteria will be measured through theDEA model. Next, the quantitative measurement of the supplier will be executed through the ZOGP model. Lastly, the results from both methods will be compared to see the consistency and to select the best supplier. The details about every step are explained in Figure 1.

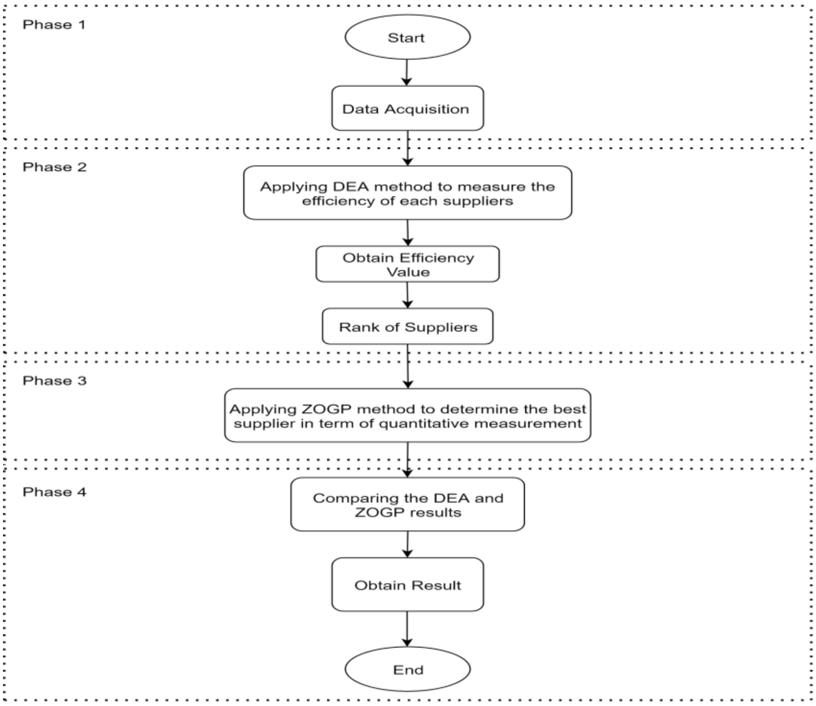


Figure 1: Conceptual framework of the study

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### *3.2 Data Acquisition*

The one month data in this study were collected from a food manufacturing company which is located in Johor Bahru, Malaysia as stated in Table 1.

Table 1: Measurement Scales

| 10 - Point Likert Scale | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Extremely Dissatisfied | Very Dissatisfied | Dissatisfied | Maybe Dissatisfied | Moderate | Above Moderate | Maybe Satisfied | Satisfied | Very Satisfied | Extremely Satisfied |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

This research focused on the three main raw ingredients for the production of lyre cake which are flour, cocoa powder and sugar. There are three suppliers for each of the raw materials. Table 2, Table 3 and Table 4 show the qualitative and quantitative data for flour, cocoa powder and sugar, respectively. The data on raw material price and rate of the accuracy of delivery time, accuracy of shipping amount and of response in quality problems were used for qualitative measurement in DEA. The input for DEA method is the raw materials price where the least price indicates the highest performance of the supplier. Based on Silalahi et al. [1], the output used are the accuracy of delivery time, accuracy of shipping amount and of response in quality problems which are measured by the Likert scale as shown in Table 1 where the higher the scale, the better performance of the supplier. The assessment for the output is done by the staff who deals directly with the supplier and is able to rate the performance of each supplier or DMUs. On the other hand, the data processing using ZOGP for the quantitative measurement are the demand of the company, purchasing costs, maximum supply delay time, discount rate, delivery time, defect ratio and price.

Table 2: Qualtitative and Quantitative Data of Flour Supply

| Criteria | Supplier 1 | Supplier 2 | Supplier 3 |
|---|---|---|---|
| Price per kg (RM) | 1.74 | 1.84 | 1.68 |
| Accuracy Delivery Time Rate | 9 | 8 | 9 |
| Accuracy Shipping Amount Rate | 9 | 9 | 9 |
| Response in Quality Problems Rate | 9 | 8 | 9 |
| Supply of Company (kg) | 23,000 | 23,500 | 24,200 |
| Maximum Supply Delay Time (days) | 15 | 16 | 13 |
| Discount Rate (%) | 17 | 16 | 13 |
| Delivery Time (days) | 8 | 4 | 3 |
| Defect Ratio (%) | 1 | 3 | 1 |

p-ISSN 1675-7939; e-ISSN 2289-934

Table 3: Qualtitative and Quantitative Data of Cocoa Powder Supply

| Criteria | Supplier 1 | Supplier 2 | Supplier 3 |
|---|---|---|---|
| Price per kg (RM) | 6.90 | 7.20 | 7.15 |
| Accuracy Delivery Time Rate | 10 | 9 | 9 |
| Accuracy of Shipping Amount Rate | 9 | 9 | 9 |
| Response in Quality Problems Rate | 9 | 8 | 9 |
| Supply of Company (kg) | 12,570 | 10,000 | 9,400 |
| Maximum Supply Delay Time (days) | 8 | 12 | 10 |
| Discount Rate (%) | 9 | 4 | 4.40 |
| Delivery Time (days) | 2 | 7 | 5 |
| Defect Ratio (%) | 1 | 3 | 1 |

Table 4: Qualtitative and Quantitative Data of Sugar Supply

| Criteria | Supplier 1 | Supplier 2 | Supplier 3 |
|---|---|---|---|
| Price per kg (RM) | 2.25 | 2.45 | 2.60 |
| Accuracy of Delivery Time Rate | 9 | 9 | 9 |
| Accuracy of Shipping Amount Rate | 8 | 9 | 9 |
| Response in Quality Problems Rate | 8 | 9 | 8 |
| Supply of Company (kg) | 12,000 | 15,000 | 10,000 |
| Maximum Supply Delay Time (days) | 8 | 7 | 14 |
| Discount Rate (%) | 14 | 9 | 9 |
| Delivery Time (days) | 6 | 4 | 9 |
| Defect Ratio (%) | 3 | 1 | 3 |

### *3.3 Data Envelopment Analysis (DEA) Method*

Charnes, Cooper and Rhodes [7] have proposed the very first DEA model where it is called after their initials as a CCR model. The CCR is the Constant Scale Returns (CRS) radial model where the CCR model can be categorized into two models which are input-oriented CCR model and output-oriented CCR model. Input-oriented CCR model is intended to minimize the inputs used by maintaining the output produced while output-oriented CCR model focused on maximizing output produced by maintaining the input used [11]. This study applied a CCR input oriented model and LINGO software is used to solve the mathematical model. The model is illustrated as in equation (1) until equation (4) by Pitchipoo et al. [26]. This method delivers the efficiency score for each of the DMU with the range between 0 to 1 where less

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productive units or inefficiency are identified with an efficiency score that is less than 1. Then, the data of efficiency score obtained from DEA will be used to determine the ranking of suppliers. The higher the value of efficiency score, the higher the ranking order. Supposedly there are n DMUs where each DMUj (j = 1, 2, 3 ..., n) utilizes *m* inputs and *s* outputs. The CCR output oriented model as in [7] is as follow:

Minimize

$$h_j = \sum_{i=1}^{m} v_i X_{i0} \quad (1)$$

Subject to

$$\sum_{r=1}^{s} u_r Y_{r0} = 1 \quad (2)$$

$$\sum_{i=1}^{m} v_i X_{ij} - \sum_{r=1}^{s} u_r Y_{rj} \geq 0,\ j = 1, \ldots n \quad (3)$$

$$u_r, v_i \geq \varepsilon, r = 1, \ldots, s, i = 1, \ldots, m \quad (4)$$

where
$v_i$ = Weights of input *i*
$u_r$ = Weights of output
$x_{ij}$ = Input
$y_{rj}$ = Output
*j* = DMU or supplier
*m* = Number of inputs
*s* = Number of outputs
*n* = Number of DMU or supplier

If $h_j = 1$, it means that DMUj is completely efficient relative to other units, otherwise it is inefficient.

### *3.4 Zero-One Goal Programming (ZOGP) Method*

The general form of a ZOGP model can be expressed as follows as in [27].

Minimize

$$\sum_{i=1}^{n} p_k (d_i^+ + d_i^-) \quad (5)$$

Subject to

Hard contraints: $$\sum_{j=1}^{n} a_j x_j = b_i \quad (6)$$

Soft contraints: $$\sum_{j=1}^{n} a_j x_j - d_i^+ + d_i^- = b_i \quad (7)$$

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Such that

$$x_{j=0 \; or \; 1} \quad ; \quad x_j, d_i^+, d_i^- \geq 0 \quad \text{for } i = 1, \dots, m \;\; ; \;\; j = 1, \dots, n \qquad (8)$$

where,

$$x_{j=0 \; or \; 1} = \begin{cases} 0 \;, \; do \; not \; select \; the \; supplier \\ 1 \;, \; select \; the \; supplier \end{cases}$$

$p_k$ = the priority and the goal of the constraints
$a_j$ = the input parameter of supplier *j*
$x_j$ = the decision variable, *j* for supplier that will be selected
$d_i^+$ = the positive deviation variable or amount by which goal is overachieved
$d_i^-$ = the negative deviation variable or amount by which goal is underachieved
$b_i$ = the target or aspiration level that is assigned by the company

### *3.4.1 Decision Variables*

The model's decision variables of flour suppliers are defined as follows:

$x_1$ = decision variable for flour supplier 1
$x_2$ = decision variable for flour supplier 2
$x_3$ = decision variable for flour supplier 3

The decision variables of cocoa powder suppliers are defined as follows:

$y_1$ = decision variable for cocoa powder supplier 1
$y_2$ = decision variable for cocoa powder supplier 2
$y_3$ = decision variable for cocoa powder supplier 3

The decision variable of sugar suppliers are defined as follows:

$z_1$ = decision variable for sugar supplier 1
$z_2$ = decision variable for sugar supplier 2
$z_3$ = decision variable for sugar supplier 3

### *3.4.2 Hard Constraints*

The model's decision variables of flour suppliers are defined as follows:

Hard constraints are the constraints that are compulsory to be achieved in the ZOGP model. The hard constraints in this study are the demands from the company and the cost of the raw materials. The company needs 25000kg of flour, 15000kg of cocoa powder and 16000kg of sugar every month. Nevertheless, each supplier has their own capacity limit in supplying the raw materials to the company. The demand constraints from each of the raw materials are as follow:

Flour: $$23000x_1 + 23500x_2 + 24200x_3 \leq 25000 \qquad (9)$$

Cocoa powder: $$12570y_1 + 10000y_2 + 9400y_3 \leq 15000 \qquad (10)$$

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Sugar: $$12000z_1 + 15000z_2 + 10000z_3 \leq 16000 \quad (11)$$

The company has set the budget that the maximum purchasing price for each packet of the raw materials are RM 1.90 for each packet of flour, RM 8.00 for each packet of cocoa powder and RM 2.80 for each packet of sugar. Hence, the purchasing department has the aim to minimize the cost as much as possible. The following constraints are constructed in order to ensure that the purchasing price will not exceed the company budget.

Flour: $$1.74x_1 + 1.84x_2 + 1.68x_3 \leq 1.90 \quad (12)$$

Cocoa powder: $$6.9y_1 + 7.2y_2 + 7.15y_3 \leq 8.00 \quad (13)$$

Sugar: $$2.25z_1 + 2.45z_2 + 2.6z_3 \leq 2.80 \quad (14)$$

In order to choose the best supplier for each raw material, the constraints are as follow:

$$x_1 + x_2 + x_3 = 1 \quad (15)$$

$$y_1 + y_2 + y_3 = 1 \quad (16)$$

$$z_1 + z_2 + z_3 = 1 \quad (17)$$

### *3.4.3 Soft Constraints*

The soft constraints that are constructed in the ZOGP model will have positive deviation, $d_i^+$ and negative deviation, $d_i^-$. This model is attempted to fulfil these soft constraints by minimizing the deviations with the aspiration values where the aspiration values in the right-hand side of the soft constraints are obtained from the company. Then, the resulting value of these deviation variables will be explained in the next section. The soft constraints in this study are the maximum supply of delay time allowed by the company, the discount rate and the delivery time of items preferred by the company and the defect ratio compromised by the company. The supply delay time can affect the company production as well as the supplier reputation. However, unexpected cases may occur which cause the delay in supply. The maximum supply delay times (in day) tolerable by the company for each of the raw material are as follow:

Flour: $$15x_1 + 16x_2 + 13x_3 + d_1^- - d_1^+ = 14 \quad (18)$$

Cocoa powder: $$8y_1 + 12y_2 + 10y_3 + d_1^- - d_1^+ = 11 \quad (19)$$

Sugar: $$8z_1 + 7z_2 + 14z_3 + d_1^- - d_1^+ = 12 \quad (20)$$

The company is also looking forward to selecting suppliers with the best amount of discount offered. The discount given from the supplier is the advantage to the company in saving their manufacturing cost. The constraints are as follow:

Flour: $$0.17x_1 + 0.16x_2 + 0.16x_3 + — d_2^+ = 0.15 \quad (21)$$

Cocoa powder: $$0.09y_1 + 0.04y_2 + 0.044y_3 + d_2^- -— = 0.03 \quad (22)$$

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Sugar: $$0.14z_1 + 0.09z_2 + 0.09z_3 + d_2^- - d_2^+ — 08 \quad (23)$$

The maximum delivery time assigned by the mart is at most 5 days for flour, 4 days for cocoa powder and 7 days for sugar. Then, the company can choose the supplier which supplies the raw materials in the least time.

Flour: $$8x_1 + 4x_2 + 3x_3 + d_3^- - d_3^+ = 5 \quad (24)$$

Cocoa powder: $$2y_1 + 7y_2 + 5y_3 + d_3^- - d_3^+ = 4 \quad (25)$$

Sugar: $$6z_1 + 4z_2 + 9z_3 + d_3^- - d_3^+ = 7 \quad (26)$$

The company aims for the defective items to be at most 2.5% for flour and cocoa powder while 3% for sugar. The constraints are as follow:

Flour: $$0.01x_1 + 0.03x_2 + 0.01x_3 + d_4^- - d_4^+ = 0.025 \quad (27)$$

Cocoa powder: $$0.01y_1 + 0.03y_2 + 0.01y_3 + d_4^- - d_4^+ = 0.025 \quad (28)$$

Sugar: $$0.03z_1 + 0.01z_2 + 0.03z_3 + d_4^- - d_4^+ = 0.03 \quad (29)$$

### *3.4.4 Deviation Variables*

The model of this study attempts to minimize the deviation variables in the set of soft constraints. Table 5 shows the deviation variables to be minimized for sugar supplier soft constraints.

Table 5: The deviation variable to be minimized in each soft constraint for sugar supply.

| Soft constraints | The deviation variable to be minimized |
|---|---|
| Minimize the supply delay time<br>$8z_1 + 7z_2 + 14z_3 \leq 12$<br>$8z_1 + 7z_2 + 14z_3 + d_1^- - d_1^+ = 12$ | $d_1^+$ |
| Maximize the discount offered to the company<br>$0.14z_1 + 0.09z_2 + 0.09z_3 \geq 0.08$<br>$0.14z_1 + 0.09z_2 + 0.09z_3 + d_2^- - d_2^+ = 0.08$ | $d_2^-$ |
| Minimize the delivery time of raw material to arrive<br>$6z_1 + 4z_2 + 9z_3 \leq 7$<br>$6z_1 + 4z_2 + 9z_3 + d_3^- - d_3^+ = 7$ | $d_3^+$ |
| Minimize percentage of defect ratio<br>$0.03z_1 + 0.01z_2 + 0.03z_3 \leq 0.030.03z_1 + 0.01z_2 +$<br>$0.03z_3 + d_4^- - d_4^+ = 0.03$ | $d_4^+$ |

### *3.4.5 Goal and Priority*

The goals to be maximized or minimized from every soft constraint has been decided earlier which depends on the target and aims of the company. Then, the soft constraints are set in different priorities accordingly based on their importance to the company. The priority of each goal is defined as follow:

p-ISSN 1675-7939; e-ISSN 2289-934

**First Priority (P1)**: Minimize the supply delay time

Flour: $$15x_1 + 16x_2 + 13x_3 + d_1^- - d_1^+ = 14 \quad (18)$$

Cocoa powder: $$8y_1 + 12y_2 + 10y_3 + d_1^- - d_1^+ = 1 \quad (19)$$

Sugar: $$8z_1 + 7z_2 + 14z_3 + d_1^- - d_1^+ = 12 \quad (20)$$

**Second Priority (P2)**: Maximize the discount offered to the company

Flour: $$0.17x_1 + 0.16x_2 + 0.16x_3 + d_2^- - d_2^+ = 0.15 \quad (21)$$

Cocoa powder: $$0.09y_1 + 0.04y_2 + 0.044y_3 + d_2^- - d_2^+ = 0.03 \quad (22)$$

Sugar: $$0.14z_1 + 0.09z_2 + 0.09z_3 + d_2^- - d_2^+ = 0.08 \quad (23)$$

**Third Priority (P3)**: Minimize the delivery time of the raw material

Flour: $$8x_1 + 4x_2 + 3x_3 + d_3^- - d_3^+ = 5 \quad (24)$$

Cocoa powder: $$2y_1 + 7y_2 + 5y_3 + d_3^- - d_3^+ = 4 \quad (25)$$

Sugar: $$6z_1 + 4z_2 + 9z_3 + d_3^- - d_3^+ = 7 \quad (26)$$

**Fourth Priority (P4)**: Minimize the defect ratio of raw material to arrive

Flour: $$0.01x_1 + 0.03x_2 + 0.01x_3 + d_4^- - d_4^+ = 0.025 \quad (27)$$

Cocoa powder: $$0.01y_1 + 0.03y_2 + 0.01y_3 + d_4^- - d_4^+ = 0.025 \quad (28)$$

Sugar: $$0.03z_1 + 0.01z_2 + 0.03z_3 + d_4^- - d_4^+ = 0.03 \quad (29)$$

## 4. RESULTS AND DISCUSSION

This section discusses the findings of the DEA and ZOGP method for the supplier selection problem. The case study is performed in a food manufacturing company with five selected criteria of suppliers which are price and rating for accuracy of delivery time, accuracy of shipping amount and response in quality problems for the qualitative measurement. On the other hand, the demand of the company, purchasing costs, maximum supply delay time, discount rate, delivery time, defect ratio and price are for the quantitative measurement to choose the best suppliers. The result of efficiency value for the supplier in terms of qualitative criteria is measured through the DEA model while the quantitative measurement of the supplier is measured through the ZOGP model. Both mathematical models are solved using LINGO Software.

p-ISSN 1675-7939; e-ISSN 2289-934

### *4.1 Efficiency Score and Ranking of DMUs Using DEA Model*

Table 6 presents the efficiency scores for each supplier or DMUs and the ranking of the suppliers by using the DEA model for each type of raw materials. The suppliers with the efficiency value of 1 are the most efficient suppliers. The higher the value of efficiency score, the higher the ranking order. Thus, it can be seen that the best suppliers for flour and cocoa powder are Supplier 3 and Supplier 1 respectively, while Supplier 1 and Supplier 2 are the best suppliers for sugar.

Table 6: Efficiency score of each DMU using DEA model

| Flour | | | Cocoa Powder | | | Sugar | | |
|---|---|---|---|---|---|---|---|---|
| DMU | Efficiency score | Rank | DMU | Efficiency score | Rank | DMU | Efficiency score | Rank |
| Supplier 1 $(x_1)$ | 0.9975 | 2 | Supplier 1 $(y_1)$ | 1.0000 | 1 | Supplier 1 $(z_1)$ | 1.0000 | 1 |
| Supplier 2 $(x_2)$ | 0.9130 | 3 | Supplier 2 $(y_2)$ | 0.9583 | 3 | Supplier 2 $(z_2)$ | 1.0000 | 1 |
| Supplier 3 $(x_3)$ | 1.0000 | 1 | Supplier 3 $(y_3)$ | 0.9650 | 2 | Supplier 3 $(z_3)$ | 0.9423 | 3 |

### *4.2 Optimal value of the ZOGP Model*

Table 7 shows the optimal value for each supplier for different types of raw materials. The value of 1 indicates that the supplier has been chosen as the best supplier. Based on the results, Supplier 3, Supplier 1 and Supplier 2 have been chosen as the best supplier for flour, cocoa powder and sugar respectively.

Table 7: Optimal value of each DMU of the ZOGP model

| Flour | | Cocoa Powder | | Sugar | |
|---|---|---|---|---|---|
| Suppliers | Optimal Value | Suppliers | Optimal Value | Suppliers | Optimal Value |
| Supplier 1 $(x_1)$ | 0.000000 | Supplier 1 $(y_1)$ | 1.000000 | Supplier 1 $(z_1)$ | 0.000000 |
| Supplier 2 $(x_2)$ | 0.000000 | Supplier 2 $(y_2)$ | 0.000000 | Supplier 2 $(z_2)$ | 1.000000 |
| Supplier 3 $(x_3)$ | 1.000000 | Supplier 3 $(y_3)$ | 0.000000 | Supplier 3 $(z_3)$ | 0.000000 |

There are four goals with priorities according to the company's decision involved in this study where the details of the deviation values for the best suppliers for flour, cocoa powder and sugar are shown in Table 8, 9 and 10. All of the goals have been fully achieved as indicated by the values of $d_1^+ = 0$ for P1, P3 and P4 and $d_1^- = 0$ for P2 respectively in Table 8, 9 and 10.

p-ISSN 1675-7939; e-ISSN 2289-934

In Table 8, the value of $d_1^+ = 0$ for P1 indicates that the first priority goal has been achieved while the value of $d_1^- = 1$ indicates that there is a decrease in maximum supply delay time up to 1 day. The company's target of having at least 15% discounts from the supplier is also achieved with an extra of 10% discount as indicated by the deviation value of $d_2^+ = 0.1$. The third priority goal which is to acquire 5 days of delivery time from the supplier is fully achieved by the value of $d_3^+ = 0$ while the value of $d_3^- = 2$ shows that there is a decrease of delivery time up to two days. Lastly the value of $d_4^+ = 0$ and $d_4^- = 0.15$ indicates that the fourth priority goal has been fully achieved with 15% decrease in the defect ratio. Hence, the soft constraints for flour has been fully achieved by Supplier 3.

Table 8: The deviation values for Supplier 3 of Flour Supplier

| Goal with Priority | $d_i^+$ | $d_i^-$ | Goal Achievement |
|---|---|---|---|
| P1 | 0.000000 | 1.000000 | Achieved |
| P2 | 0.100000 | 0.000000 | Achieved |
| P3 | 0.000000 | 2.000000 | Achieved |
| P4 | 0.000000 | 0.150000 | Achieved |

Next, Table 9 shows the values of deviation variables for Supplier 1 of cocoa powder. The value of $d_1^- = 3$ shows that there is a decrease in maximum supply delay time up to 3 days where the actual target from the company is 11 days. The company's target of having 3% discounts from the cocoa powder suppliers has been achieved since the value of $d_2^- = 0$. In fact, by choosing supplier 1, the company will get an additional 60% discount as indicated by the value of $d_2^+ = 0.60$. Then, the deviation value of $d_3^- = 2$ shows that there is a decrease of the delivery time up to two days where the company's original target is to acquire 4 days of delivery time. The fourth priority goal is to allow 2.5% of defect ratio and since the value of $d_4^- = 0.15$, it shows that there is a decrease of 15% of the defect ratio. Hence, the soft constraints for cocoa powder had been fully achieved by Supplier 1.

Table 9: The deviation values for Supplier 1 of Cocoa Powder Supplier

| Goal Priority | $d_i^+$ | $d_i^-$ | Goal Achievement |
|---|---|---|---|
| P1 | 0.000000 | 3.000000 | Achieved |
| P2 | 0.600000 | 0.000000 | Achieved |
| P3 | 0.000000 | 2.000000 | Achieved |
| P4 | 0.000000 | 0.150000 | Achieved |

Table 10 shows the values of deviation variables for Supplier 2 of the sugar supplier. The company has set the maximum supply delay time for sugar is 12 days. This goal has been fully achieved and the value of $d_1^- = 5$ shows that there is a decrease in maximum supply delay time up to 5 days. The company's aim of having 8% discounts from the supplier has been fully achieved as indicated by the value of $d_2^- = 0$ and by choosing Supplier 2, the company will receive an extra of 10% discount as shown by the value of $d_2^+ = 0.10$. Since the negative

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deviation value of delivery time is $d_3^- = 3$, there is a decrease of delivery time up to three days where the actual targeted delivery time was seven days. Lastly the value of $d_4^+ = 0$ and $d_4^- = 0.20$ indicates that the fourth priority goal has been fully achieved with 20% decrease in the defect ratio. Thus, all of the goals for sugar suppliers have been fully achieved by Supplier 2.

Table 10: The deviation values for Supplier 2 of Sugar Supplier

| Goal Priority | $d_i^+$ | $d_i^-$ | Goal Achievement |
|---|---|---|---|
| P1 | 0.000000 | 5.000000 | Achieved |
| P2 | 0.100000 | 0.000000 | Achieved |
| P3 | 0.000000 | 3.000000 | Achieved |
| P4 | 0.000000 | 0.200000 | Achieved |

### *4.3 Comparison results of DEA and ZOGP methods*

Finally, the best supplier for the raw materials will be chosen from the result obtained in the DEA and ZOGP model. The efficiency score from the DEA method is in terms of qualitative measurement while the ZOGP method is in terms of quantitative measurement as shown in Table 11, Table 12 and Table 13. Based on Table 11, Table 12 and Table 13, Supplier 3, Supplier 1 and supplier 2 have been chosen as the best suppliers for flour, cocoa powder and sugar, respectively. Therefore, both methods show consistent results for the best suppliers in terms of qualitative and quantitative measurement.

Table 11: Ranking of Suppliers from DEA and ZOGP methods for Flour

| Method | DEA | | ZOGP |
|---|---|---|---|
| Suppliers | Efficiency score | Rank | Optimal value |
| Supplier 1 ($x_1$) | 0.9975 | 2 | 0.0000 |
| Supplier 2 ($x_2$) | 0.9130 | 3 | 0.0000 |
| Supplier 3 ($x_3$) | 1.0000 | 1 | 1.0000 |

Table 12: Ranking of Suppliers from DEA and ZOGP methods for Cocoa Powder

| Method | DEA | | ZOGP |
|---|---|---|---|
| Suppliers | Efficiency score | Rank | Optimal value |
| Supplier 1 ($y_1$) | 1.0000 | 1 | 1.0000 |
| Supplier 2 ($y_2$) | 0.9583 | 3 | 0.0000 |
| Supplier 3 ($y_3$) | 0.9650 | 2 | 0.0000 |

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Table 13: Ranking of Suppliers from DEA and ZOGP methods for Sugar

| Method | DEA | | ZOGP |
|---|---|---|---|
| Suppliers | Efficiency score | Rank | Optimal value |
| Supplier 1 $(z_1)$ | 1.0000 | 1 | 0.0000 |
| Supplier 2 $(z_2)$ | 1.0000 | 1 | 1.0000 |
| Supplier 3 $(z_3)$ | 0.9423 | 3 | 0.0000 |

## 5. CONCLUSION

This study focuses on optimizing supplier selection by using the DEA, which is later compared to the ZOGP method for a food manufacturing company in Johor, Malaysia. The efficiency score is obtained from the DEA method in terms of qualitative measurement while the ZOGP method identified one of the best possible suppliers of the three different types of raw materials in quantitative measurement. The data for the qualitative measurement were obtained through Likert scale and was justified by the representative of the company. This research has determined the best supplier by comparing the results from both methods. Thus, Supplier 3, Supplier 1 and Supplier 2 have been chosen as the best suppliers for flour, cocoa powder and sugar, respectively. Findings from this study indicate the feasibility of using DEA and ZOGP in solving the problem of supplier selection involving multiple criteria in terms of qualitative and quantitative measurement. Future study may consider other constraints in choosing the best supplier such as transportation cost, product return, the percentages of service satisfaction, warranty degree, quality control time, supply chain costs and maximum and minimum order quantities, as well as considering other mathematical methods such as fuzzy Goal Programming.

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p-ISSN 1675-7939; e-ISSN 2289-934