Jurnal Mantik, 6 (2) (2022) 1929-1937

Published by:Institute of Computer Science (IOCS)

Jurnal Mantik

Journal homepage: www.iocscience.org/ejournal/index.php/mantik/index

Study Of The Optimization Of Measurenment Efficiency Model Of Fuzzy Data Envelopment Analysis

Desi Vinsensia[1], Yulia Utami[2], Awaluddin Fitra[3], Rina Nanda Hanifa[4], Mestriawan Barasa[5]

Study Program Management Informatics ,Informatics Engineering , STMIK Pelita Nusantara

E-mail: desivinsensia87@gmail.com

ARTICLE INFO

Article history:
Received: Jun 30, 2022
Revised: Jul 17, 2022
Accepted: Jul 25, 2022

Keywords:
Efficiency,
performance ,
Data envelopment analysis (DEA),
Fuzzy DEA.

ABSTRACT

The performance of determination efficiency is affected by both situation certainty and uncertainty. The goal of this study is to develop fuzzy data envelopment analysis models for measuring efficiency performance with the Data envelopment analysis (DEA) method and also a fuzzy method that considers the inputs and outputs of the decision making unit (DMU) on intuitionistic triangular fuzzy numbers. On model development, a step procedure in measurement efficiency performance is given. For processing its efficiency, there is input and output representation on useful intuitionistic triangular fuzzy numbers as output and input estimation data. The application of the fuzzy model to the given case demonstrates that it can be used and is capable of measuring efficiency performance performance more efficiently.

1. Introduction

In a business environment, companies must ensure all planned goals can be achieved with a good result. Therefore, measurement performance is required to determine the level of achievement destination..The company measured efficiency to find out where input is used to produce output, or, in other words, how much output is produced in relation to the input used. Measurement efficiency can also be used to know which inputs only those who don't know how to use efficiently or know the output that should be upgraded with available inputs can conduct repair on these inputs. This method can be used to measure efficiency through Data Envelopment Analysis (DEA). DEA is a non-parametric method with multifactor input and output that is used to evaluate level efficiency relative to Decision Making Units (DMUs).

In development, the DEA model has been widely used in various fields. However, the general DEA model uses input and output variables containing one score (crisp) or one score sure. Whereas in reality, that's a possible score, neither input nor output variables could be determined by certain so-introduced fuzzy concepts. Integration of fuzzy concepts into the DEA model has been conducted by a number of researchers previously with different applications. Various fields The application of fuzzy DEA includes efficiency service health [1], [2],[3] , measurement transportation system efficiency [4], as well as measurement efficiency cost, efficiency income[5], and efficiency profit [6]. The basic output characteristics of the fuzzy DEA model could be distinguished. namely, the output that is still fuzzy [7], the output that is crisp [8], [9] and the output that is fuzzy and crisp [10]. However, the situations in daily life, multiple inputs and outputs simultaneously have subjective, linguistic, and form uncertainty and have an intuitive fuzzy essence or even obscurity [11]

So, this study leads the creation of a fuzzy DEA model that is, in essence, institutionalistic, with inputs and outputs that are owned and shown by an intuitive triangular fuzzy number. The aim of this paper is to develop a fuzzy DEA model that represents the input and the output as an instuitionistic triangular fuzzy number. To show how fuzzy DEA's model used in this study, the case studies were used to show how the model using to measure the company's efficiency by calculating the score of its own performance.

2. Method

2.1 Development of Fuzzy Data Envelopment Analysis Model

The Idea of This study developed a data environment analysis (DEA) model by [12] to evaluate performance [13] with a determined score efficiency, but with the inherent uncertainty nature of the inputs and outputs. In this study, the measurement efficiency performance was achieved through data envelopment analysis (DEA). This DEA model is capable of analyzing efficiently each take-up unit decision or a decision making unit (DMU) with multiple inputs and multiple outputs [14]. In the study, DEA model was developed. This is the classic DEA CCR model, with natural input and output uncertainty. The inputs and outputs are looked at with a rough set of fuzzy triangular numbers and an institutionalistic twist. In this study, the inputs and outputs are on defined fuzzy environment as triangular instuitionistic fuzzy number (TIFN).

Definition 1 : fuzzy triangular instuitionistics a ̃= (a^l,a^m,a^u)is the set of real numbers in R , with function membership as following :

$$\mu_{\tilde{a}}(x) = \begin{cases} \dfrac{x - a^m}{a^m - a^l}\mu_{\tilde{a}}, & jika\ a^l \le x \le a^m \\ \mu_{\tilde{a}}, & jika\ x = a^m \\ \dfrac{a^u - x}{a^u - a^m}\mu_{\tilde{a}}, & jika\ a^m < x \le a^u \\ 0, & jika\ x < a^l\ atau\ x > a^u \end{cases}$$

And there are non - membership function that can be defined as following :

$$\vartheta_{\tilde{a}}(x) = \begin{cases} \frac{a^m - x + (x - a^l)}{a^m - a^l}\vartheta_{\tilde{a}}, & jika\ a^l \le x < a^m \\ \vartheta_{\tilde{a}}, & jika\ x = a^m \\ \frac{x - a^m + (a^u - x)}{a^u - a^m}\vartheta_{\tilde{a}}, & jika\ a^m \le x < a^u \\ 1, & jika\ x < a^l\ atau\ x > a^m \end{cases} \quad (2)$$

$\mu_{\tilde{a}}$is the maximum membership degree and $\vartheta_{\tilde{a}}$is the minimum non-membership degree that satisfies the following conditions: $0 \le \mu_{\tilde{a}} \le 1$, $0 \le \vartheta_{\tilde{a}} \le 1$, $0 \le \mu_{\tilde{a}} + \vartheta_{\tilde{a}} \le 1$. [11]

On this proposed model development, consider maximizing output with input and output on DMU to *j* defined instuitionistic triangular fuzzy number as following :

$\tilde{x}_{ij} = \left((x_{ij}^l, x_{ij}^m, x_{ij}^u); \mu_{x_{ij}}; \vartheta_{x_{ij}}\right)$ and $\tilde{y}_{rj} = \left((y_{rj}^l, y_{rj}^m, y_{rj}^u); \mu_{y_{rj}}, \vartheta_{y_{rj}}\right)$. At the $x_{ij}^l, x_{ij}^m, x_{ij}^u$ stated value that x_{ij}^l= value *x* input *lower* , x_{ij}^m= value x input *medium* , x_{ij}^u= value x input *upper* . Whereas for $(y_{rj}^l, y_{rj}^m, y_{rj}^u)$states y_{rj}^l= value of *y* output *lower* , y_{rj}^m= value of y output *medium*, y_{rj}^u= value of y output *upper* .

Then the fuzzy DEA model can be denoted as following :

$$Maximize \quad \sum_{r=1}^{s} u_r \tilde{y}_{rp} \quad (3)$$

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

Constraints :

$\sum_{i=1}^{m} v_i \tilde{x}_{ip} = \tilde{1}$ (4)

$\sum_{r=1}^{s} u_r \tilde{y}_{rj} - \sum_{i=1}^{m} v_i \tilde{x}_{ij} \leq \tilde{0},$ (5)

$u_r \geq 0; r = 1,2, \ldots, s$

$v_i \geq 0; i = 1,2, \ldots, m$

Where :

u_r = *rth* output vector weight

$v_i i$ =th input vector weight

$\tilde{x}_{ij}$ =*i* -th intuitive triangular fuzzy number on the *j*-th DMU .

$\tilde{y}_{rj}$ = the output value which is triangular instuitionistic fuzzy number to *r* on the *j-th* DMU.

Definition 2 . suppose there is fuzzy triangular instuitionistics $\tilde{a}_i = \left(\left(a_i^l, a_i^m, a_i^u\right);\ \mu_i, \vartheta_i\right)$. Then the ranking aggregate function is as follows:

$$\bar{R}\left(\sum_{i=1}^{n} \tilde{a}_i\right) = (1 + \min \mu_i - max\vartheta_i) \times \sum_{i=1}^{n} \frac{R(\tilde{a}_i)}{1+\mu_i-\vartheta_i} = \frac{(1+\min \mu_i - \max v_i)}{6} \sum_{i=1}^{n}\left(a_i^l + a_i^m + a_i^u\right) \quad (6)$$

Definition 2 above is ranking the aggregate will be converted on a DEA model containing fuzzy triangular instuitionistics on inputs and outputs.

Then the DEA model of triangular instuitionistics fuzzy numbers is used are :

$$Maksimumkan \qquad \sum_{r=1}^{s} u_r\left(\left(y_{rp}^l, y_{rp}^m, y_{rp}^u\right);\ \mu_{y_{rp}}, \vartheta_{y_{rp}}\right)$$

Constraints : (4)

$$\sum_{i=1}^{m} v_i\left(\left(x_{ip}^l, x_{ip}^m, x_{ip}^u\right); \mu_{x_{ip}}, \vartheta_{x_{ip}}\right) = \tilde{1}$$

$$\sum_{r=1}^{s} u_r\left(\left(y_{rj}^l, y_{rj}^m, y_{rj}^u\right);\ \mu_{y_{rj}}, \vartheta_{y_{rj}}\right) - \sum_{i=1}^{m} v_i\left(\left(x_{ij}^l, x_{ij}^m, x_{ij}^u\right); \mu_{x_{ij}}, \vartheta_{x_{ij}}\right) \leq \tilde{0},$$

$u_r \geq 0; r = 1,2, \ldots, s$

$v_i \geq 0; i = 1,2, \ldots, m$

3. Results And Discussion

From the derivated formula in the previous section, the DEA model of triangular instuitionistics fuzzy numbers is used:

$$Maksimumkan \qquad \sum_{r=1}^{s} u_r\left(\left(y_{rp}^l, y_{rp}^m, y_{rp}^u\right);\ \mu_{y_{rp}}, \vartheta_{y_{rp}}\right) \quad (5)$$

Constraints :

$$\sum_{i=1}^{m} v_i\left(\left(x_{ip}^l, x_{ip}^m, x_{ip}^u\right); \mu_{x_{ip}}, \vartheta_{x_{ip}}\right) = \tilde{1}$$

$$\sum_{r=1}^{s} u_r\left(\left(y_{rj}^l, y_{rj}^m, y_{rj}^u\right);\ \mu_{y_{rj}}, \vartheta_{y_{rj}}\right) - \sum_{i=1}^{m} v_i\left(\left(x_{ij}^l, x_{ij}^m, x_{ij}^u\right); \mu_{x_{ij}}, \vartheta_{x_{ij}}\right) \leq \tilde{0},$$

$u_r \geq 0; r = 1,2, \ldots, s$
$v_i \geq 0; i = 1,2, \ldots, m$

Here we developed the algorithm to measurement fuzzy DEA model efficiency:

Step 1. Analyze and identify the input and output variables for every DMU owned. Then define estimation or estimation performance for each input and output variable on the DMU.

Step 2. Estimate score the performance of the input and output variables of each DMU.

Step 3. Define a DEA fuzzy model

Step 4. Transformation equation (4) into form **definition 2** for the crips model.

Step 5. Solve the DEA fuzzy model with the linear programming method.Completion of this DEA fuzzy model was conducted as many times as DMU owned.

Step 6. Counting efficiency performance from step model 4th, the efficient DMU analyzed based on the ranking[15] that has been obtained.

3.1 Numerical Example

The fuzzy DEA model that has been proposed will be implemented next on a case by case basis in order to know that the proposed model could be implemented. Data used in the implementation used case on this study adapted from a previous study by [16]

Step 1: Identify the inputs and outputs of given case . In this case, there are 8 DMU with 4 inputs and 2 outputs. Input in study this is cost fare worker , (I_1), cost ingredient standard (I_2), Cost inventory (I_3), and time production (I_4). Output is profit (O_1), Revenue (O_2). Following procedure step fuzzy DEA solution that has been built .

Step 2. Estimating score performance Estimate score the performance of the input and output variables of each DMU is carried out by the fuzzification process to form triangular instuitionistic fuzzy number like in the table. 1 and table 2 explain about the output of data for fuzzy DEA.

Table 2

Estimated input data for DEA fuzzy solution

DMU	Input 1 (l,m,u ; μ, ϑ)	Input 2 (l,m,u ; μ, ϑ)	Input 3 (l,m,u ; μ, ϑ)	Input 4 (l,m,u ; μ, ϑ)
1	(71.6,72.35,73.10; 0.4,0.5)	(12.6,14.35,16.10; 0.7, 0.3)	(53.09,54.7.56.31; 1.0, 0.0)	(3.55, 5.2, 6.85; 0.8, 0.1)
2	(67.14,68,32,69.50; 0.7, 0.2)	(22.3,23.6,24.9; 0.6, 0.1)	(53.09, 54.7, 56.31; 0.9, 0.1)	(3.9, 6, 8.1; 0.5, 0.3)
3	(72.07,72.35, 72.63; 1.0, 0.0)	(8.5,10.5,12.5; 0.4, 0.2)	(53.09, 54.7, 56.31; 0.8.0.2)	(3.55, 5.2, 6.85; 0.7, 0.3)
4	(71.7, 72.35, 73.00; 0.9, 0.1)	(10.58,13.2,15.82; 0.8, 0.1)	53.09, 54.7, 56.31; 0.7, 0.1)	(3.5, 5.2, 6.85; 0.9, 0.1)
5	(67.44, 68.32, 69.2; 0.8, 02)	(6.64, 9.14, 11.64; 0.6, 0.3)	(53.09, 54.7, 56.31; 0.6, 0.2)	(3.9, 6, 8.1; 1.0, 0.0)
6	(67.83,68.32, 68.81; 0.7, 0.3)	(19.61, 22.31, 25.01; 0.8, 0.2)	(53.09, 54.7, 56.31; 0.5, 0.4)	(3.9, 6, 8.1; 0.8, 0.2)
7	(70.47,72.35, 74.47; 0.6, 0.1)	(4.73,7.23, 9.73; 1.0, 0.0)	(53.09, 54.7, 56.31; 0.6, 0.1)	(3.5, 5.2, 6.85; 0.6, 0.4)
8	(66.62,68.32,70.02; 0.5, 0.4)	(21.55, 24.3, 27.45; 0.8, 0.2)	(53.09, 54.7, 56.31; 0.7, 0.3)	(3.9, 6, 8.1; 0.7, 0.2)

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

Table 2
Estimated input data for DEA fuzzy solution

DMU	Output 1 (l,m,u ; μ, ϑ)	Output 2 (l,m,u ; μ, ϑ)
1	(132,240,348; 0.9,0.1)	(168, 200, 232; 0.1, 0.0)
2	(389, 410, 431; 0.6, 0.2)	(40, 80, 120; 0.8, 0.1)
3	(92, 158, 224; 0.9, 0.0)	(65, 95, 125; 0.7, 0.1)
4	(152, 235, 318; 0.7, 0.2)	(25, 50, 75; 0.5, 0.2)
5	(181, 198, 215; 0.8, 02)	(100, 112, 124; 0.4, 0.3)
6	(200, 300, 400; 0.6, 0.4)	(80, 98, 116; 0.7, 0.2)
7	(100, 250, 400; 0.4, 0.2)	(78, 102, 126; 0.6, 0.2)
8	(80, 150, 220; 1.0, 0.0)	(112, 152, 192; 0.9, 0.1)

Step 3 :Modelling fuzzy DEA accordingly with the proposed formulation model and on step to 4: transform the model on step 3 to the shape of the crisp model . So from the data obtained on then the DEA fuzzy model for DMU 1 could formulated as following :

$$Maximize \quad \left[\frac{1+min(0.9;1.0)-maks\ (0.1;0.0)}{6}\right](132+240+348)u_1 + (168+200+232)u_2$$

Subject to :

$$\left[\frac{1+\min(0.4;0.7;1.0;0.8)-maks\ (0.5;0.3;0.0;0.1)}{6}\right](71.6+72.35+73.10)v_1 + (12.6+14.35+16.10)v_2 + (53.09+54.7+56.31)v_3 + (3.55+5.2+6.85)v_4 = 1$$

$$\left[\left(\frac{1+\min(0.9;1.0)-maks\ (0.1;0.0)}{6}\right)(132+240+348)u_1 + (168+200+232)u_2\right] - \left[\left(\frac{1+\min(0.4;0.7;1.0;0.8)-maks\ (0.5;0.3;0.0;0.1)}{6}\right)(71.6+72.35+73.10)v_1 + (12.6+14.35+16.10)v_2 + (53.09+54.7+56.31)v_3 + (3.55+5.2+6.85)v_4\right] \leq 0$$

$$\left[\left(\frac{1+\min(0.6;0.8)-maks\ (0.1;0.2)}{6}\right)(389+410+431)u_1 + (40+80+120)u_2\right] - \left[\left(\frac{1+\min(0.7;0.6;0.9;0.5)-maks\ (0.2;0.1;0.1;0.3)}{6}\right)(67.14+68.32+69.50)v_1 + (22.3+23.6+24.9)v_2 + (53.09+54.7+56.31)v_3 + (3.9+6+8.1)v_4\right] \leq 0$$

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

$$\left[\left(\frac{1+\min(0.9;0.7)-maks\ (0.0;0.1)}{6}\right)(92+158+224)u_1+(65+95+125)u_2\right] - \left[\left(\frac{1+\min(1.0;0.4;0.8;0.7)-maks\ (0.0;0.2;0.2;0.3)}{6}\right)(72.07+72.35 + 72.63)v_1+(8.5+10.5+12.5)v_2+(53.09+54.7+56.31)v_3 + (3.55+5.2+6.85)v_4\right] \leq 0$$

$$\left[\left(\frac{1+\min(0.7;0.5)-maks\ (0.2;0.2)}{6}\right)(152+235+318)u_1+(25+50+75)u_2\right] - \left[\left(\frac{1+\min(0.9;0.8;0.7;0.9)-maks\ (0.1;0.1;0.1;0.1)}{6}\right)(71.7+72.35 + 73.00)v_1+(10.58+13.2+15.82)v_2+(53.09+54.7+56.31)v_3 + (3.5+5.2+6.85)v_4\right] \leq 0$$

$$\left[\left(\frac{1+\min(0.8;0.4)-maks\ (0.2;0.3)}{6}\right)(181+198+215)u_1+(100+112+124)u_2\right] - \left[\left(\frac{1+\min(0.8;0.6;0.6;1.0)-maks\ (0.2;0.3;0.2;0.0)}{6}\right)(67.44+68.32 + 69.2)v_1+(6.64+9.14+11.64)v_2+(53.09+54.7+56.31)v_3 + (3.9+6+8.1)v_4\right] \leq 0$$

$$\left[\left(\frac{1+\min(0.6;0.7)-maks\ (0.4;0.2)}{6}\right)(200+300+400)u_1+(80+98+116)u_2\right] - \left[\left(\frac{1+\min(0.7;0.8;0.5;0.8)-maks\ (0.3;0.2;0.4;0.2)}{6}\right)(67.83+68.32 + 68.81)v_1+(19.61+22.31+25.01)v_2+(53.09+54.7+56.31)v_3 + (3.9+6+8.1)v_4\right] \leq 0$$

$$\left[\left(\frac{1+\min(0.4;0.6)-maks\ (0.2;0.2)}{6}\right)(100+250+400)u_1+(78+102+126)u_2\right] - \left[\left(\frac{1+\min(0.6;1.0;0.6;0.6)-maks\ (0.1;0.0;0.1;0.4)}{6}\right)(70.47+72.35 + 74.47)v_1+(4.73+7.23+9.73)v_2+(53.09+54.7+56.31)v_3 + (3.5+5.2+6.85)v_4\right] \leq 0$$

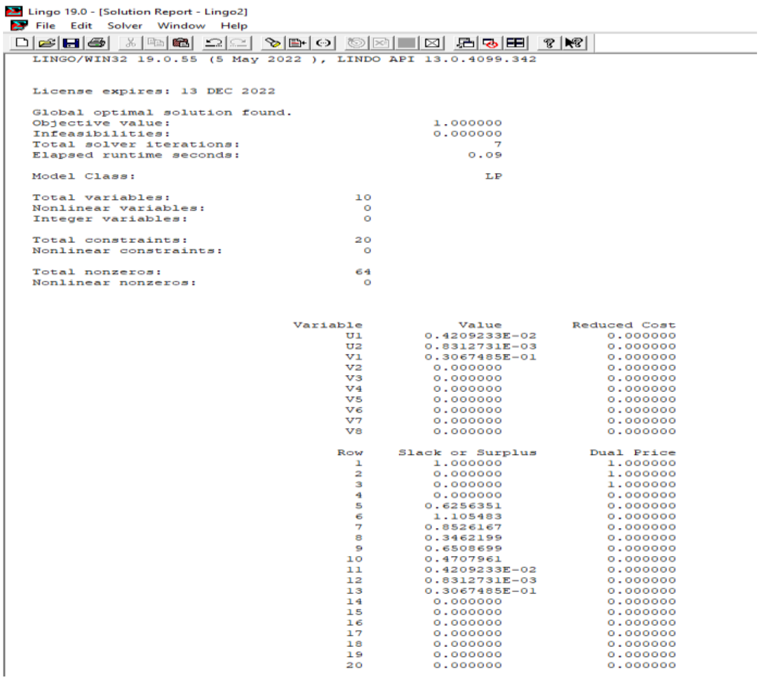
Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

$$\left[\left(\frac{1+\min(1.0;0.9)-maks\ (0.0;0.1)}{6}\right)(80+150+220)u_1+(112+152+192)u_2\right] - \left[\left(\frac{1+\min(0.5;0.8;0.7;0.7)-maks\ (0.4;0.2;0.3;0.2)}{6}\right)(66.62+68.32 + 70.02)v_1+(21.55+24.3+27.05)v_2+(53.09+54.7+56.31)v_3 + (3.9+6+8.1)v_4\right] \le 0$$

$u_r \ge 0; r = 1,2;$

$v_i \ge 0; i = 1,2,3$

Step 5: The formulation solved with using with LINGO and this paper using LINGO student version, shown figure 1.



```
Lingo 19.0 - [Solution Report - Lingo2]
File  Edit  Solver  Window  Help

LINGO/WIN32 19.0.55 (5 May 2022 ), LINDO API 13.0.4099.342

License expires: 13 DEC 2022

Global optimal solution found.
Objective value:                              1.000000
Infeasibilities:                              0.000000
Total solver iterations:                             7
Elapsed runtime seconds:                          0.09

Model Class:                                        LP

Total variables:                     10
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   20
Nonlinear constraints:                0

Total nonzeros:                      64
Nonlinear nonzeros:                   0


                     Variable           Value        Reduced Cost
                           U1    0.4209233E-02           0.000000
                           U2    0.8312731E-03           0.000000
                           V1    0.3067485E-01           0.000000
                           V2         0.000000           0.000000
                           V3         0.000000           0.000000
                           V4         0.000000           0.000000
                           V5         0.000000           0.000000
                           V6         0.000000           0.000000
                           V7         0.000000           0.000000
                           V8         0.000000           0.000000

                          Row    Slack or Surplus      Dual Price
                            1         1.000000           1.000000
                            2         0.000000           1.000000
                            3         0.000000           1.000000
                            4         0.000000           0.000000
                            5        0.6256351           0.000000
                            6         1.105483           0.000000
                            7        0.8526167           0.000000
                            8        0.3462199           0.000000
                            9        0.6508699           0.000000
                           10        0.4707961           0.000000
                           11    0.4209233E-02           0.000000
                           12    0.8312731E-03           0.000000
                           13    0.3067485E-01           0.000000
                           14         0.000000           0.000000
                           15         0.000000           0.000000
                           16         0.000000           0.000000
                           17         0.000000           0.000000
                           18         0.000000           0.000000
                           19         0.000000           0.000000
                           20         0.000000           0.000000
```

Figure 1. Output Fuzzy DEA DMU 1 Program LINGO student version

The solution with LINGO is as many as DMU owned. In this implementation case, owned DMU, there are 8, so there are 8 times processing with LINGO.

Step 6: Based on measurement efficiency with LINGO, we obtained that of 8 DMUs analyzed, there are 2 efficient DMUs, i.e., DMU 1 and DMU 2 . Besides that, there are 6 DMUs that aren't efficient, namely DMU 3, DMU 4, DMU 5, DMU 6, DMU 7, and DMU 8.

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

4. Conclusion

Study this discuss development of data envelopment analysis (DEA) models in measure efficiency performance which performance input and the output have existing characteristics on environment uncertainty . In resolve uncertainty that approached with set intuitionistic triangular fuzzy numbers . Generally function defined fuzzy membership , however with triangular instuitionistic fuzzy number defined also non- membership function and calculated score aggregate rank efficiency each take- up unit decision (DMU). The proposed DEA fuzzy model implemented and the result of the proposed model could applied for measure level efficiency in a company for planning production could efficient.

References

[1] K. Miszczynska and P. M. Miszczyński, "Measuring the efficiency of the healthcare sector in Poland – a window-DEA evaluation," *Int. J. Product. Perform. Manag.*, 2021, doi: 10.1108/IJPPM-06-2020-0276.

[2] Y. C. Zhu and S. K. Au, "Bayesian data driven model for uncertain modal properties identified from operational modal analysis," *Mech. Syst. Signal Process.*, vol. 136, p. 106511, 2020, doi: 10.1016/j.ymssp.2019.106511.

[3] T. C. C. Nepomuceno, W. M. N. Silva, K. T. C. Nepomuceno, and I. K. F. Barros, "A DEA-Based Complexity of Needs Approach for Hospital Beds Evacuation during the COVID-19 Outbreak," *J. Healthc. Eng.*, vol. 2020, p. 8857553, 2020, doi: 10.1155/2020/8857553.

[4] M. Bagheri, A. Ebrahimnejad, S. Razavyan, F. Hosseinzadeh Lotfi, and N. Malekmohammadi, *Fuzzy arithmetic DEA approach for fuzzy multi-objective transportation problem*, vol. 22, no. 2. Springer Berlin Heidelberg, 2022. doi: 10.1007/s12351-020-00592-4.

[5] M. Bagheri, A. Ebrahimnejad, S. Razavyan, F. Hosseinzadeh Lotfi, and N. Malekmohammadi, "Solving the fully fuzzy multi-objective transportation problem based on the common set of weights in DEA," *J. Intell. Fuzzy Syst.*, vol. 39, no. 3, pp. 3099–3124, 2020, doi: 10.3233/JIFS-191560.

[6] A. Ashrafi and M. Mansouri Kaleibar, "Cost, Revenue and Profit Efficiency Models in Generalized Fuzzy Data Envelopment Analysis," *Fuzzy Inf. Eng.*, vol. 9, no. 2, pp. 237–246, 2017, doi: 10.1016/j.fiae.2017.06.007.

[7] I. Giyanti and A. Indrasari, "Model Pengukuran Efisiensi Perusahaan Berbasis Fuzzy Data Envelopment Analysis," in *Seminar dan Konferensi Nasional IDEC*, 2018, pp. 7–8. [Online]. Available: https://idec.ft.uns.ac.id/wp-content/uploads/2018/05/ID049.pdf

[8] S. Bray, L. Caggiani, and M. Ottomanelli, "Measuring transport systems efficiency under uncertainty by fuzzy sets theory based data envelopment analysis: Theoretical and practical comparison with traditional DEA model," *Transp. Res. Procedia*, vol. 5, pp. 186–200, 2015, doi: 10.1016/j.trpro.2015.01.005.

[9] S. Bray, L. Caggiani, M. Dell'Orco, and M. Ottomanelli, "Measuring Transport Systems Efficiency under Uncertainty by Fuzzy Sets Theory based Data Envelopment Analysis," *Procedia - Soc. Behav. Sci.*, vol. 111, no. November, pp. 770–779, 2014, doi: 10.1016/j.sbspro.2014.01.111.

[10] A. Tharwat, B. El-Demerdash, and I. El-Khodary, *Developing an Input Oriented Data Envelopment Analysis Model with Fuzzy Uncertainty in Variables*. Springer International Publishing, 2019. doi: 10.1007/978-3-030-01662-3_13.

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

[11] J. Puri and S. P. Yadav, "Intuitionistic fuzzy data envelopment analysis: An application to the banking sector in India," *Expert Syst. Appl.*, vol. 42, no. 11, pp. 4982–4998, 2015, doi: 10.1016/j.eswa.2015.02.014.

[12] S. A. Edalatpanah, "A Data Envelopment Analysis Model with," *Int. J. Data Envel. Anal.*, vol. 7, no. 4, pp. 47–58, 2019.

[13] W. D. Cook, K. Tone, and J. Zhu, "Data envelopment analysis: Prior to choosing a model," *Omega (United Kingdom)*, vol. 44, pp. 1–4, 2014, doi: 10.1016/j.omega.2013.09.004.

[14] P. Peykani, E. Mohammadi, A. Emrouznejad, M. S. Pishvaee, and M. Rostamy-Malkhalifeh, "Fuzzy data envelopment analysis: An adjustable approach," *Expert Syst. Appl.*, vol. 136, pp. 439–452, 2019, doi: 10.1016/j.eswa.2019.06.039.

[15] J. Puri and S. P. Yadav, "A concept of fuzzy input mix-efficiency in fuzzy DEA and its application in banking sector," *Expert Syst. Appl.*, vol. 40, no. 5, pp. 1437–1450, 2013, doi: 10.1016/j.eswa.2012.08.047.

[16] D. Vinsensia and Y. Utami, "Study Of Fuzzy Goal Programming Model To Production Planning Problems Approach," *J. Tek. Inform. C.I.T Medicom*, vol. 13, no. 2, pp. 75–81, 2021, doi: 10.35335/cit.vol13.2021.149.pp75-81.

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.