International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

DEA's HFLTS-Slack Super Efficiency Model for Prioritizing Activities

Dahlan Abdullah[1], Cut Ita Erliana[2]

Submitted: 27/04/2023 **Revised**: 24/06/2023 **Accepted**: 08/07/2023

Abstract: Research on benchmarking is currently getting more and more attention, along with the need for optimal utilization of existing resources to achieve the best possible results. One of the benefits of benchmarking is the evaluation and quality assurance efforts of the results achieved from an activity. Benchmarking efforts are carried out to evaluate a part of an activity, whether it is efficient or not. It is important to study or evaluate an activity not only after it is finished but before it is carried out. So far, research has only focused on evaluating an activity after completion. Evaluating an activity before it is carried out is important, considering the limited budget available so that not all activities are eligible to be funded. So far, the model for evaluating existing activities only focuses on quantitative inputs and outputs. Evaluating activities before they are carried out sometimes requires input from the community and experts. The existing input is not only in the form of numbers or quantitatively. However, existing assessments can also be given qualitatively and involve many parties.Existing benchmarking models have not been able to accommodate this. One excellent benchmarking method is Data Envelopment Analysis (DEA). Still, this method has limitations in that it can only handle quantitative data and cannot accommodate assessments from many parties, even though it is possible that one of the variables in this benchmarking concerns assessment from the public or experts. Therefore, this study will combine Hesitant Fuzzy Linguistic Terms Sets (HFLTS)-Slack Super Efficiency DEA, where HFLTS increases DEA's ability to receive input and output from many parties, not only quantitative but also qualitative, and even each appraiser has a different assessment with varying levels of confidence in the assessment, while Slack Super Efficiency can determine priority scales of activities based on the results of the HFLTS-DEA. This research will be useful findetermining the priority scale of activities, one of which is determining the priority scale of activities at Malikussaleh University. What needs to be understood is that the resulting model will be made into a web-based software so that the software can be adjusted based on needs, input, and output and receive various input from many parties, both quantitative and qualitative. Through this research, it is hoped that the HFLTS-Super Efficiency DEA model can produce good evaluation principles and good governance so that every activity that is financed either from internal organizational funds or from taxes paid by the community can be carried out properly and can be determined which activities are truly a priority. to be held and which ones can be postponed or even not held.

Keywords— *Benchmarking*; *Data Envelopment Analysis*; *Hesitant Fuzzy Linguistic Term Sets*; *Slack Super Efficiency*; *Good Governance*.

1. Introduction

At this time, the public is increasingly aware of the importance of benchmarking efforts, including evaluation and quality assurance in each section and activities carried out by an organization or company (J. S. Liu, Lu, Lu, & Lin, 2013). Research on benchmarking an activity has been carried out a lot, such as research conducted by (Bessent & Bessent, 1980) which examined efficiency in elementary schools with Data Envelopment Analysis (DEA), the efficiency of carrying out activities in junior high schools in England (Bradley, Johns, & Millington, 2001), and efficiency in high schools in Finland (Kirjavainen & Loikkanent, 1998). According to several researchers, the great attention to the implementation of activities is due to the large amount of responsibility that exists in connection with the implementation of these activities and evaluation of these activities should be carried out before these activities are carried out (Martínez et al., 2019). There has been researching from a number of researchers who examined the application of DEA in evaluating an activity before the activity is carried out (Du, Liang, & Zhu, 2010) (Munoz, 2016).

[1]*Department of Informatics, Universitas Malikussaleh, Aceh, Indonesia*
E-mail: dahlan@unimal.ac.id
[2]*Department of Industrial Engineering, Universitas Malikussaleh, Aceh, Indonesia*
E-mail: cutitha@unimal.ac.id

The party implementing the activity needs to make maximum use of the existing budget, in the midst of a limited budget so that the activities carried out are really the activities that are needed (Agasisti & Pérez-Esparrells, 2010). Most of the benchmarking methods used in research use Data Envelopment Analysis (DEA). There are 2 (two) approaches to efficiency in DEA, namely measurement of efficiency and super-efficiency (Tran, Mao, Nathanail, Siebers, & Robinson, 2019). Efficiency measurement is based on determining efficient and inefficient Decision Making Units (DMUs) (Charnes, Cooper, & Rhodes, 1979), while super-efficiency measurements are based on determining efficient DMU priorities (Tone, 2001).

Determination of super-efficiency is basically determined based on slack determination and is intended for evaluation before the activity is carried out (Guo, Lee, & Lee, 2017). However, this method certainly has limitations if there are a number of appraisers who provide assessments not only quantitatively in the form of numbers, but assessments are given in qualitative form such as the expressions "very important", "important", and so on. This coupled with each assessor has a varying level of confidence in the assessment they give, there are those who are "very sure", "sure", and even "less sure". Standard Data Envelopment Analysis will not be able to overcome this (Ehrgott, Holder, & Nohadani, 2018). Hesitant Fuzzy Linguistic Term Sets (HFLTS) are well known for their ability to summarize judgments from various qualitative and quantitative parties with various levels of confidence (Tang & Liao, 2019). The HFLTS-Super Efficiency DEA model is expected to be able to evaluate the feasibility level and priority scale of activities that can receive input from the public and experts in carrying out the activity benchmarking process. One application of the HFLTS-Super Efficiency DEA model is in the field of determining priority scales of activities at Malikussaleh University. Malikussaleh University as one of the State Universities (PTN) finances the implementation of existing activities sourced from APBN funds. Therefore, as a form of accountability from the State Budget which originates from taxes paid by the people, the HFLTS-Super Efficiency DEA Model will assist in determining the appropriate priority scale of activities so that the right activities can be funded and implemented amidst a limited budget. The resulting model will be used in the form of web-based software so that the software can be adjusted based on needs, input, output, and receive various inputs from many parties, both quantitative and qualitative.

2. Material and Method

Wang et al. is the first to propose the Stochastic Data Envelopment Analysis Method [14]. The basic principle is to establish quantile functions that can avoid crossing quantiles while also proposing estimates for stochastic frontier measurements [15]. Due to restricted knowledge from many parameters, the probability theory is used in the benchmarking model, which is one of the key factors in developing the Stochastic Data Envelopment Analysis [16]. The focus of Stochastic Data Envelopment Analysis research then shifts to deciding the upper and lower bounds for output and input, but no researchers have addressed the stochastic issue that includes a situation where the assessor gives an uncertain assessment [17]. Since a number of researchers recognize that there are unknown inputs and outputs, and humans are more at ease making decisions in the form of linguistic variables, the Fuzzy Data Envelopment Analysis (FDEA) method was created [18].

Many FDEA models have been developed such as the ideal-seeking FDEA [19], the tolerance and possibility FDEA[20] the FDEAwith double frontiers [21] and the cross-efficiency FDEA [22]. However, sometimes qualitative data sourced from linguistic variables are inaccurate and the time available for decision makers is limited so that doubts arise. In this situation, Hesitant Fuzzy developed into Hesitant Fuzzy Data Envelopment Analysis can be used [23]. This research will develop a Hesitant Fuzzy DEA model which in addition can perform the benchmarking process on the stochastic problem, it can also benchmark the conditions that contain Hesitant Fuzzy elements.

The benchmarking process will be carried out to measure the efficiency of the study programs at Malikussaleh University using the HF-SDEA method. There are a number of DMUs with input and output that are qualitative in nature so that they require measurements involving the Hesitant Fuzzy method and Stochastic Data Envelopment Analysis. The stages of research can be seen in Figure 1.

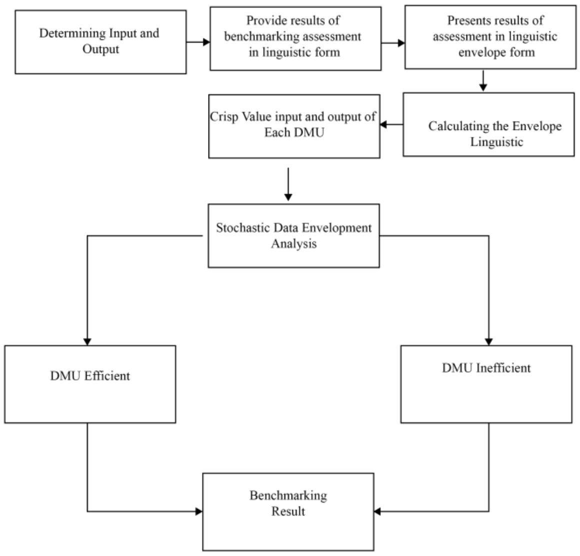

Fig. 1 Research Method

Figure 1 shows that the Hesitant Fuzzy approach is required in the benchmarking phase where there are inputs and outputs that contain elements of uncertainty, where the evaluation cannot be given in the form of crisp values and the assessor has reservations about giving an assessment. The assessors will begin by conducting a benchmarking process and providing an evaluation in the form of a linguistic form for Fuzzy Hesitant. In the linguistic envelope type, all of the assessments will be combined. The crisp value of each input and output for each DMU will then be determined using the linguistic values found in the linguistic envelope. The next step will be to perform a Stochastic Data Development Analysis, which will produce measurement results indicating which DMU is efficient and which DMU is inefficient, particularly if the data contains stochastic data.

A. Linguistic Form

As can be seen in Equation 1, linguistic forms are represented as a collection of linguistic words.

$$S = \{neither, very\ low, low, medium, high, very\ high, absolute\} \quad (1)$$

One of the benefits of Hesitant Fuzzy is that assessors can provide evaluation results in linguistic form during the benchmarking process. It can be shown in Equation 1 that there are many words that can be used to make an evaluation.

B. Envelope Form

Equation 2 shows the envelope form, which is a linguistic set of intervals.

$$env(H_S) = [H_{S^-}, H_{S^+}], H_{S^-} \leq H_{S^+} \quad (2)$$

Where H_{S^-} and H_{S^+} are defined as follows:

$$H_{S^+} = max(s_i) = s_j \in H_s \text{ and } s_i \leq s_j \forall i$$

$$H_{S^-} = min(s_i) = s_j \in H_s \text{ and } s_i \geq s_j \forall i \quad (3)$$

The envelope type incorporates a negative and positive evaluation in one unit, as shown by Equations 2 and 3. If assessors are reluctant to evaluate an evaluation value, they may include an assessment in the form of a variety of assessments during the benchmarking process. This will assist the appraiser in making an evaluation and increase the accuracy of the assessment during the benchmarking process.

C. Calculating the Envelope Linguistic

Equations 4 and 5 can be used to figure out what the linguistic envelope values are.

$$p_i^+ = \Delta(\delta(\Delta^{-1}(s_t, \propto)_{ij}^+)) \ \forall j \epsilon \{1, \ldots,)T\}$$

$$p_i^- = \Delta(\delta(\Delta^{-1}(s_t, \propto)_{ij}^-)) \ \forall j \epsilon \{1, \ldots,)T\} \quad (4)$$

$$V^t = (p_1^t, p_2^t, \ldots, p_T^t) \quad (5)$$

Equations 4 and 5 demonstrate the outcomes of each assessor's negative and positive evaluations during the benchmarking phase. The final values of inputs and outputs for each DMU will be obtained in the form of crisp values by integrating this assessment in the form of a negative and positive value.

D. DEA with CCR Model

Equation 6 reveals a classic DEA with the CCR Model.

$$Maximize \ \propto = \frac{\sum_{r=1}^{k} u_r y_{r0}}{\sum_{s=1}^{l} v_s x_{s0}} \quad (6)$$

Limit or constraint function:

$$u_r, v_s \geq 0; r = 1, ..., k; s = 1,.., l$$

Where:

α = Efficiency object s

k = observed output object s

y_{is} = the number of outputs I produced as a result of object s

x_{js} = number of inputs i used by object s

u_i = the output weight i produced by object s

v_j = the input weight i given by object s

The aim of the above equation is to find the maximum number of outputs from DMU_n that are weighted, by holding the number of inputs weighted on a value less than or equal to one and the ratio of outputs weighted by the input weighted, of all DMUs.

E. Stochastic Data Envelopment Analysis (SDEA)

SDEA model proposed by Olesen and Petersen[8] can be used for benchmarking with stochastic data. The benchmarking method is a stochastic phenomenon in the form of probability that can often only be measured by its frequency distribution and can be approached by an interval function whose shape will mimic, i.e. it will reach a maximum value at some times while others will reach a minimum point. Equations 7 and 8 can be used to measure the efficiency of each DMU using the SDEA equation.

$$\ln C = f(w, y) + \ln u + \ln v \quad (7)$$

Where C is the total cost required, w is the input vector, y is the output vector, and e = u + v is the term error. Where u is a variable that can be managed and represents inefficiency. v is an uncontrollable (random) factor as well as a noise word. The performance ratio can be expressed in the following way.

$$CEFF_n = \frac{C_{min}}{C_n} = \frac{\exp\left[fc(w^n, y^n) + \ln\left(u_{c_{min}}\right)\right]}{\exp\left[fc(w^n, y^n) + \ln\left(u_{c_n}\right)\right]} = \frac{u_{c_{min}}}{u_{c_n}}$$

(8)

The determination of variable v, which is a random entity with noise, has its own set of issues. Especially if there are many people involved in the evaluation and each one has a different point of view. This is a distinct fault in the SDEA process.

F. Hesitant Fuzzy – Stochastic Data Envelopment Analysis (HF-SDEA)

Equation 9 illustrates the use of the fuzzy reluctant approach in deciding the index ranking of the Decision Making Unit (DMU).

$$I(\tilde{E}_r) = \frac{\sum_{i=0}^{n}\left((E_r)_{\propto_i}^{u} - c\right)}{\sum_{i=0}^{n}\left((E_r)_{\propto_i}^{u} - c\right) - \sum_{i=0}^{n}\left((E_r)_{\propto_i}^{L} - d\right)} \quad (9)$$

Where is C_{Min} for Equation 8 based on Equation 9 that can be seen in Equation 10.

$$C_{Min} = \min_{\iota, J}\left\{(\acute{E}_r)_{\propto_\iota}^{L}\right\} \quad (10)$$

And C_n for Equation 8 is based on the Equation 9 that can be seen in Equation 11.

$$C_n = \max_{\iota, J}\left\{(\acute{E}_r)_{\propto_\iota}^{U}\right\} \quad (11)$$

3. Result and Discussion

A. Decision Making Unit (DMU)

As shown in Table 1, the DMU used in this analysis is in the context of Malikussaleh University study programs.

Table 1. DECISION MAKING UNIT (DMU)

DMU	Input		Output	
	No. of Lecturers	**No. of Students**	**No. of Research**	**No. of Graduates**
Information Technology	18	567	7	671
Civil Engineering	27	750	6	535
Architectural Engineering	16	387	6	187
Industrial Engineering	18	451	6	311
Chemical Engineering	26	351	6	261
Mechanical Engineering	24	501	6	236
Electrical Engineering	20	432	6	331
Agribusiness	18	701	6	284
Agro-Technology	35	837	6	291
Aquaculture	11	576	6	243
Communication Science	12	734	6	291
Political Science	12	273	6	201
Sociology	14	491	6	211
Anthropology	10	189	6	127
Jurisprudence	51	1101	6	473
Medicine	31	291	6	301
Management	49	1307	6	1379
Economic Development	12	862	6	301
Accounting	24	1273	6	421

Table 1 displays inputs and outputs in the form of direct values that can be calculated, but there are also inputs in the form of stochastic values that include uncertainties, such as: The university environment for input and output is measured by graduate users' satisfaction levels. As a result, HF-SDEA can be used to quantify input values for the university setting and output values for stakeholder satisfaction. Assume the results of the calculations are as shown in Table 2.

TABLE 2 THE RESULT OF HF-SDEA

DMU	Input			Output		
	Number of Lecturers	**Number of Students**	**University Environment**	**Number of Research**	**Number of Graduates**	**Stakeholder Satisfaction**
Information Technology	18	567	0.77	7	671	0.91
Civil Engineering	27	750	0.35	6	535	0.51
Architectural Engineering	16	387	0.61	6	187	0.59

Industrial Engineering	18	451	0.69	6	311	0.69
Chemical Engineering	26	351	0.56	6	261	0.79
Mechanical Engineering	24	501	0.62	6	236	0.62
Electrical Engineering	20	432	0.71	6	331	0.59
Agribusiness	18	701	0.76	6	284	0.66
Agro-Technology	35	837	0.81	6	291	0.76
Aquaculture	11	576	0.61	6	243	0.56
Communication Science	12	734	0.71	6	291	0.81
Political Science	12	273	0.61	6	201	0.74
Sociology	14	491	0.59	6	211	0.72
Anthropology	10	189	0.66	6	127	0.69
Jurisprudence	51	1101	0.57	6	473	0.49
Medicine	31	291	0.62	6	301	0.81
Management	49	1307	0.63	6	1379	0.79
Economic Development	12	862	0.67	6	301	0.69
Accounting	24	1273	0.74	6	421	0.83

B. *Testing resuts*

The following is the complete type of programming with HF-SDEA.

Maximize:

671 U1 + 7 U2+0.91 U3

Subject to:

18 V1 + 567 V2+0.77 V3= 1

671 U1 + 7 U2+0.91 U3 - 18 V1 - 567 V2-0.77 V3 <= 0

535 U1 + 6 U2+0.51 U3 - 27 V1 - 750 V2-0.35 V3 <= 0

187 U1 + 6 U2+0.59 U3 - 16 V1 - 387 V2-0.61 V3 <= 0

311 U1 + 6 U2+0.69 U3 - 18 V1 - 451 V2-0.69 V3 <= 0

261 U1 + 6 U2+0.79 U3 - 26 V1 - 351 V2-0.56 V3 <= 0

236 U1 + 6 U2+0.62 U3 - 24 V1 - 501 V2-0.62 V3 <= 0

331 U1 + 6 U2+0.59 U3 - 20 V1 - 432 V2-0.71 V3 <= 0

284 U1 + 6 U2+0.66 U3 - 18 V1 - 701 V2-0.76 V3 <= 0

291 U1 + 6 U2+0.76 U3 - 35 V1 - 837 V2-0.81 V3 <= 0

243 U1 + 6 U2+0.56 U3 - 11 V1 - 576 V2-0.61 V3 <= 0

291 U1 + 6 U2+0.81 U3 - 12 V1 - 734 V2-0.71 V3<= 0

201 U1 + 6 U2+0.74 U3 - 12 V1 - 273 V2-0.61 V3 <= 0

211 U1 + 6 U2+0.72 U3 - 14 V1 - 491 V2-0.59 V3<= 0

127 U1 + 6 U2+0.69 U3 - 10 V1 - 189 V2-0.66 V3 <= 0

473 U1 + 6 U2+0.49 U3 - 51 V1 - 1101 V2-0.57 V3<= 0

301 U1 + 6 U2+0.81 U3 - 31 V1 - 291 V2-0.62 V3<= 0

1379 U1 + 6 U2+0.79 U3 - 49 V1 - 1307 V2-0.63 V3<= 0

301 U1 + 6 U2+0.69 U3 - 12 V1 - 862 V2-0.67 V3 <= 0

421 U1 + 6 U2+0.83 U3 - 24 V1 - 1273 V2-0.74 V3 <= 0

U1>=0

U2>=0

U3>=0

V1>=0

V2>=0

V3>=0

END

The efficiency testing results for each DMU based on the HF-SDEA are shown in Table 3.

Table 3. DECISION MAKING UNIT (DMU)

DMU	DEA Efficiency
Information Technology	1
Civil Engineering	1
Architectural Engineering	0.92
Industrial Engineering	0.84
Chemical Engineering	1
Mechanical Engineering	0.85
Electrical Engineering	0.85
Agribusiness	0.77
Agrotechnology	0.68
Aquaculture	1
Communication Science	1
Political Science	1
Sociology	0.99
Anthropology	1
Jurisprudence	0.65
Medical	1
Management	1
Economic Development	0.99
Accounting	0.88

Table 3 shows that the most powerful DMUs were Information Technology, Civil Engineering, Chemical Engineering, Aquaculture, Communication Science, Political Science, Anthropology, Medical, and Management, with a total of 9 (nine) DMUs.

The test results show that the HF-SDEA conducted a good benchmarking process for stochastic data under conditions that included elements of uncertainty and hesitancy. Centered on the HF-SDEA, the results of this study also include an effective and inefficient DMU. Future research should consider feasibility, need, and reputation.

4. Conclusions

The results showed that the Hesitant Fuzzy model - Stochastic Data Envelopment Analysis (HF-SDEA) can be used to benchmark stochastic data under uncertain conditions. Future research should be able to assess the productive rating of each DMU in order to determine the university's future growth priorities.

References

[1] A. Emrouznejad and G. Yang, "A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016," *Socio-Economic Planning Sciences*, vol. 61, pp. 4–8, Mar. 2018.

[2] M. Ehrgott, A. Holder, and O. Nohadani, "Uncertain Data Envelopment Analysis," *European Journal of Operational Research*, vol. 268, no. 1, pp. 231–242, Jul. 2018.

[3] C. Kahraman and E. Tolga, "Data envelopment analysis using fuzzy concept," in *Proceedings. 1998 28th IEEE International Symposium on Multiple-Valued Logic (Cat. No.98CB36138)*, 1998, pp. 338–343.

[4] M. Tavana, A. Hatami-Marbini, and A. Emrouznejad, "Productivity Growth and Efficiency Measurements in Fuzzy Environments with an Application to Health

Care," *Int. J. Fuzzy Syst. Appl.*, vol. 2, no. 2, pp. 1–35, Apr. 2012.

[5] Peijun Guo, H. Tanaka, and M. Inuiguchi, "Self-organizing fuzzy aggregation models to rank the objects with multiple attributes," *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, vol. 30, no. 5, pp. 573–580, Sep. 2000.

[6] A. Charnes, W. W. Cooper, and E. Rhodes, "Measuring the efficiency of decision making units," *European Journal of Operational Research*, vol. 2, no. 6, pp. 429–444, Nov. 1978.

[7] S. Yousefi, H. Shabanpour, R. Fisher, and R. F. Saen, "Evaluating and ranking sustainable suppliers by robust dynamic data envelopment analysis," *Measurement*, vol. 83, pp. 72–85, Apr. 2016.

[8] O. B. Olesen and N. C. Petersen, "Stochastic Data Envelopment Analysis—A review," *European Journal of Operational Research*, vol. 251, no. 1, pp. 2–21, May 2016.

[9] S. Ahmadvand and M. S. Pishvaee, "An efficient method for kidney allocation problem: a credibility-based fuzzy common weights data envelopment analysis approach," *Health Care Manag Sci*, vol. 21, no. 4, pp. 587–603, Dec. 2018.

[10] P. Peykani, E. Mohammadi, M. Rostamy-Malkhalifeh, and F. Hosseinzadeh Lotfi, "Fuzzy Data Envelopment Analysis Approach for Ranking of Stocks with an Application to Tehran Stock Exchange," *Advances in Mathematical Finance and Applications*, vol. 4, no. 1, pp. 31–43, Mar. 2019.

[11] S.-P. Wan, Y.-L. Qin, and J.-Y. Dong, "A hesitant fuzzy mathematical programming method for hybrid multi-criteria group decision making with hesitant fuzzy truth degrees," *Knowledge-Based Systems*, vol. 138, pp. 232–248, Dec. 2017.

[12] M. Ashtiani and M. A. Azgomi, "A hesitant fuzzy model of computational trust considering hesitancy, vagueness and uncertainty," *Applied Soft Computing*, vol. 42, pp. 18–37, May 2016.

[13] H. Liu, Y. Ma, and L. Jiang, "Managing incomplete preferences and consistency improvement in hesitant fuzzy linguistic preference relations with applications in group decision making," *Information Fusion*, vol. 51, pp. 19–29, Nov. 2019.

[14] Y. Wang, S. Wang, C. Dang, and W. Ge, "Nonparametric quantile frontier estimation under shape restriction," *European Journal of Operational Research*, vol. 232, no. 3, pp. 671–678, Feb. 2014.

[15] S. Jradi and J. Ruggiero, "Stochastic data envelopment analysis: A quantile regression approach to estimate the production frontier," *European Journal of Operational Research*, vol. 278, no. 2, pp. 385–393, Oct. 2019.

[16] A. Azadeh, S. Motevali Haghighi, M. Zarrin, and S. Khaefi, "Performance evaluation of Iranian electricity distribution units by using stochastic data envelopment analysis," *International Journal of Electrical Power & Energy Systems*, vol. 73, pp. 919–931, Dec. 2015.

[17] W. Liu, Y.-M. Wang, and S. Lyu, "The upper and lower bound evaluation based on the quantile efficiency in stochastic data envelopment analysis," *Expert Systems with Applications*, vol. 85, pp. 14–24, Nov. 2017.

[18] S. Lertworasirikul, S.-C. Fang, J. A. Joines, and H. L.W. Nuttle, "Fuzzy data envelopment analysis (DEA): a possibility approach," *Fuzzy Sets and Systems*, vol. 139, no. 2, pp. 379–394, Oct. 2003.

[19] A. Hatami-Marbini, S. Saati, and M. Tavana, "An ideal-seeking fuzzy data envelopment analysis framework," *Applied Soft Computing*, vol. 10, no. 4, pp. 1062–1070, Sep. 2010.

[20] A. Hatami-Marbini, A. Emrouznejad, and M. Tavana, "A taxonomy and review of the fuzzy data envelopment analysis literature: Two decades in the making," *European Journal of Operational Research*, vol. 214, no. 3, pp. 457–472, Nov. 2011.

[21] N. Ahmady, M. Azadi, S. A. H. Sadeghi, and R. F. Saen, "A novel fuzzy data envelopment analysis model with double frontiers for supplier selection," *International Journal of Logistics Research and Applications*, vol. 16, no. 2, pp. 87–98, Apr. 2013.

[22] M. Dotoli, N. Epicoco, M. Falagario, and F. Sciancalepore, "A cross-efficiency fuzzy Data Envelopment Analysis technique for performance evaluation of Decision Making Units under uncertainty," *Computers & Industrial Engineering*, vol. 79, pp. 103–114, Jan. 2015.

[23] W. Zhou, J. Chen, Z. Xu, and S. Meng, "Hesitant fuzzy preference envelopment analysis and alternative improvement," *Information Sciences*, vol. 465, pp. 105–117, Oct. 2018.

[24] Mr. Rahul Sharma. (2015). Recognition of Anthracnose Injuries on Apple Surfaces using YOLOV 3-Dense. International Journal of New Practices in Management and Engineering, 4(02), 08 - 14. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/3

[25] Kalyani, B. ., Sai, K. P. ., Deepika, N. M. ., Shahanaz, S. ., & Lohitha, G. . (2023). Smart Multi-Model Emotion Recognition System with Deep learning.

International Journal on Recent and Innovation Trends in Computing and Communication, 11(1), 139–144. https://doi.org/10.17762/ijritcc.v11i1.6061

[26] Janani, S., Dilip, R., Talukdar, S. B., Talukdar, V. B., Mishra, K. N., & Dhabliya, D. (2023). IoT and machine learning in smart city healthcare systems. Handbook of research on data-mathematical modeling in smart cities (pp. 262-279) doi:10.4018/978-1-6684-6408-3.ch014 Retrieved from www.scopus.com