Fuzzy Based Butterfly Life Cycle Algorithm for Measuring Company's Growth Performance

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***Abstract*—The previous study of the Butterfly Life Cycle Algorithm (BLCA) has been technically realized in two stages of BLCA in measuring a company's growth performance. It was based on a combined method of the Balanced Scorecard (BSC) and Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. This paper aims to continue the BLCA implementation by performing five stages of BLCA and then improve the algorithm by implementing the Fuzzy Logic (FL) conception into BSC. The implementation of the FL method transforms the bias values in four BSC parameters into a precise value to make the model more precise. A complete BLCA algorithm combined with FL is used to accurately assess companies' growth performance. By doing some corrections to the preceding study's data of contribution value, the simulation result shows the difference in the performance value of 0.0026 with the previous one.**

***Keywords*—butterfly life cycle algorithm, balanced scorecard, fuzzy logic, company growth performance**

I. INTRODUCTION

A company is a term to describe a legal group formed by a group of people that operates by offering products or services to gain profits. A company's growth and value creation are determined by interactions and combinations of several factors, including management capabilities, the development and use of its intellectual capital, financial assets, the research development innovations, and the sector of geographical location [1]. The capability to understand a company's growth might impact its plans to improve its quality [2].

In almost every field of study, nature is the most excellent source of inspiration for groundbreaking discoveries. Humans have been attempting to comprehend natural phenomena and replicate them in the real world to solve many problems [3]. Natural phenomena offer unique chances that may be turned into algorithms that efficiently solve complex problems [4]. Algorithms based on nature are commonly utilized to resolve optimization problems [3] since most optimization problems are challenging [4]. Some examples of nature-inspired algorithms are Ant Colony Optimization (ACO) for clustering [5], Bat ALGORITHM (BA) for optimization [6], Firefly Algorithm (FA) for optimization [7], Grey Wolf Optimizer (GWO) for optimization [8], and Butterfly Life Cycle Algorithm (BLCA) for measuring growth performance [9, 10].

In the BLCA study, the metamorphosis phase of the butterfly is used as an inspiration to create a novel algorithm. There are five stages in a butterfly's life cycle. The stages are egg, caterpillar, instar, chrysalis, and butterfly [9]. These stages were successfully imitated, and now can be used to assess the growth performance in many cases [10]. In the real world, each stage of a butterfly's life cycle can illustrate a company's growth from its beginning (start-ups) to maturity (mature company) [2]. BLCA algorithm can be applied with a Balanced Scorecard (BSC) and Strengths, Weaknesses, Opportunities, and Threat (SWOT) analysis approach to create a strategic planning model and calculate the company's growth performance.

In the previous study, BLCA was applied with BSC and SWOT to create a model to calculate the company's growth performance in two-phase of BLCA. BSC is a framework with criteria that measure performance from four perspectives, financial, customer, internal business process, and learning [11]. To improve the model, this paper will continue the previous studies by implementing five-phase BLCA and using Fuzzy Logic (FL) to calculate four BSC parameters precisely. The implementation of a five-phase BLCA is expected to prove the capability of BLCA to measure growth performance academically. In the end, this research is expected to create a complete BLCA model by implementing all mathematical equations from each phase of BLCA. The implementation of fuzzy logic will also make the model more precise and reliable, especially when handling biased values.

II. LITERATURE REVIEW

A. Related Works

Several problems can be solved by using an algorithm inspired by natural phenomena. Examples of nature-inspired algorithms are Ant Colony Optimization (ACO) for finding paths [5], where the result shows that the ACO algorithm has a better processing time than the other algorithm in many cases. Another example is the Bat Algorithm (BA) for optimization [6], where the result shows that BA performs superior to many different existing algorithms used to solve the engineering

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optimization problems. Another example is a study that created an algorithm inspired by a water flow to determine orders that must be accepted and schedule the orders to minimize delays and resource losses in a manufacturing company [12]. A study also presents a new approach to maximizing company profits using a Genetic Algorithm (GA) [13], and the result of the research is that GA helps improve bidding strategy for maximizing the company's profit efficiently and optimally. After observing and studying some nature-inspired algorithms, this study is conducted to explore the butterfly life cycle algorithm (BLCA) to measure the company's growth performance. BLCA works by following the life stages of a butterfly, which has 5 stages: egg, caterpillar, instar, chrysalis (pupa), and the butterfly. Each stage of BLCA has different external factors that can give either negative or positive contributions. Compared to BLCA, GA works by following human genes that will regenerate in each generation. At the same time, the ACO algorithm works by following the shortest path that an ant colony takes to search for food from the nest to the food location.

B. *Butterfly Life Cycle Algorithm*

The Butterfly Lifecycle Algorithm (BLCA) is used to measure a company's growth performance. This algorithm is designed by impersonating a lifecycle from the metamorphosis process [9]. A butterfly's natural metamorphosis process is divided into five stages: egg, caterpillar, instar, chrysalis (pupa), and butterfly [14]. BLCA will analogize the five phases of metamorphosis into a phase of company growth. External factors will influence every phase of growth. The egg and chrysalis stages have three external factors, while the caterpillar stages have four [9]. The external factors occurring in all stages are temperature [15], humidity [15], and predator. The external factor that only occurs in caterpillar stages is a leaf. In all phases, a neutral condition happens when all external factors do not appear [2].

All external factors have different probabilities of occurrence and different impacts for every stage in the lifecycle. The probability of external factors occurring in the egg and chrysalis phase is 0.20, 0.25, 0.25. 0.30 (neutral, temperature, humidity, predator) and for caterpillar phases are 0.10, 0.17, 0.17, 0.33, 0.33 (neutral, temperature, humidity, predator, leaf number). Both probability and impact are determined by using a *roulette wheel* [10].

C. *Balanced Scorecard*

A Balanced Scorecard (BSC) is a framework to measure performance from four perspectives, financial, customer, internal business process, and learning [11]. BSC is a strategic system that includes the fundamentals of a company's vision and strategic plan and input on internal and external business operations [2]. The four perspectives of BSC are presented in Fig. 1. BSC is a valuable and robust instrument for all managers, researchers, and practitioners in measuring the organization's performance [16]. Research in the Ministry of Finance in Indonesia from 2016 to 2018 shows that BSC implementation can significantly improve accountability performance [17]. The four perspectives of BSC are presented in Fig. 1.

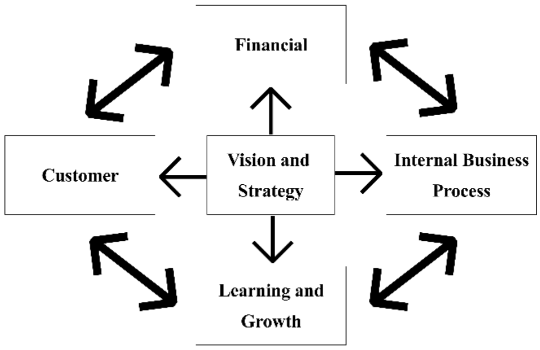

Figure 1. BSC perspective [11].

The financial perspective includes goals and metrics that serve as the ultimate performance indicators for profit-maximizing businesses and show whether a company's strategy and execution increases shareholder value [18]. The customer perspective should represent the strategy's core objectives and measurements for the strategy's customer value proposition [18]. The internal business process perspective highlights the critical operational, customer management, innovation, regulatory, and social processes the business must perform to meet its customer, revenue growth, and profit goals [18]. The learning and growth perspective highlights the goals for long-term growth and improvement of the people, system, and organization [18].

D. *Fuzzy Logic*

Fuzzy Logic (FL) is introduced as a method or an approach to computing that uses "degrees of truth" rather than the "true or false" Boolean logic (1 or 0) [19]. True or false values can be considered biased because most of the values occur between true and false [20]. According to [19], the FL has a membership function ranging from 0 to 1. The number of membership functions determines the size of an object's existence and error. Qualitative aspects of FL can be expressed using linguistic variables, while quantitative aspects can be provided with fuzzy sets represented by membership functions [21].

According to [22], FL combines exact computer language and human language that emphasizes meaning. FL is frequently used to solve ambiguity, imprecision, and bias issues. FL comes in various degrees, for example, low, medium, high, and very high [23]. FL has a reasonable probability of convincing the computed model to consider human language variables. The FL approach has three processes: fuzzification, inference (rule base), and defuzzification [24]. Fuzzification turns a crisp number into a fuzzy and is delivered to the machine for processing before being transformed into fuzzy output [25]. The inference (rule base) process creates fuzzy output by reasoning with fuzzy input and fuzzy rules that have been determined. The defuzzification process produces measurable results based on the membership function that has been determined [24].

III. RESEARCH METHODOLOGY

There are four stages of study to conduct this research, as shown in Fig. 2. This research is carried out by continuing the research that has been made previously about the Butterfly Life Cycle Algorithm (BLCA) [2, 9, 10]. In the previous study [2, 10], the two stages of the BLCA algorithm were applied to the BSC and SWOT approach to measure the company's growth performance each year. In this research, fuzzy logic will be applied to all BLCA stages to calculate the average BSC score for each year. This research will compare company performance results between the non-fuzzy BSC and the fuzzy BSC.

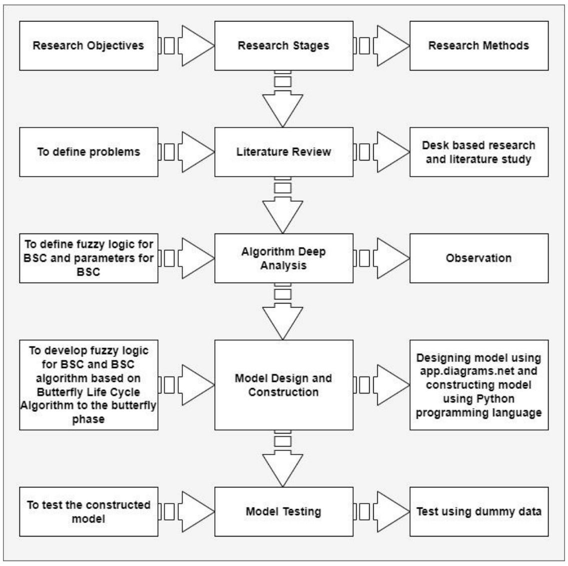

Figure 2. Research methodology block diagram [2].

In the first stage, a literature review identifies the main problems. The results show that the previous study on BLCA still did not develop the model into a complete model. It can also be considered that there is still a bias in the calculations from the previous model. Therefore, fuzzy logic will be used in calculating company performance based on BSC in all stages of BLCA. FL can be considered to get more precise and unbiased results.

The FL method, including the membership function and fuzzy rule, will be developed in the second stage. As previously mentioned, there are five stages of BLCA:egg, caterpillar, instar, chrysalis, and butterfly [10]. Those stages can be analogous to five stages of company growth: inception, survival, growth, expansion, and maturity [26]. The algorithm from the previous model will also be extended to cover those five phases in this stage. In the third stage, the Python programming language will be used to develop the model with the help of the *scikit-fuzzy* library. In the last stages, the experimental dummy data will be extended from 14 years to 31 years to cover all phases of BLCA. The dummy data is used to test the model that has been constructed.

IV. RESULT AND DISCUSSION

In the previous study, company growth was calculated by examining the company's BSC score for the last 14 years. The study only covers the egg phase and half of the caterpillar phase. The average of BSC scores is also obtained from Eq. (1), where F is finance, C is customer, BP is a business process, and L is learning, while all of the BSC parameters have the same weights. In this study, the data used is extended into 31 years to cover the whole BLCA algorithm, with the first 14 data being the same as the previous study. Also, in this study, the average BSC score is obtained by using fuzzy logic. The final result will show the differences between BLCA with fuzzy and BLCA without fuzzy. After that, this study will show the result of implementing the whole BLCA algorithm from the egg phase until the butterfly phase. Algorithm 1 shows the algorithm used in this model to calculate company growth performance.

$$Average(A) = \frac{F+C+BP+L}{4}. \quad (1)$$

Algorithm 1: Calculate Company Growth Performance

Require: *currYear* ≥ 1
  Initialize Environment
  Calculate Average (A) using Fuzzy Logic
  Calculate Accumulated Average (AA)
  Calculate Contribution (Cont.)
  Initialize x = 0
  Initialize currYear = 1
  if *currYear* ≥ 1 & *currYear* ≤ 4 **then**
    Q = AA
    while *x* ≤ *currYear* **do**
      Q = Q - Contribution
      Increment x
    end while
  else if *currYear* ≥ 5 & *currYear* ≤ 21 **then**
    Q = (AA + AAegg) / 2
    while *x* ≤ *currYear* **do**
      Q = Q - Contribution
      Increment x
    end while
  else if *currYear* ≥ 22 & *currYear* < 31 **then**
    Q = (AA + AAegg + AAcat) / 3
    while *x* ≤ *currYear* **do**
      Q = Q - Contribution
      Increment x
    end while
    Q = Q + Quality of Beauty
  end if

Based on the BLCA algorithm in Algorithm 1, to calculate company growth performance (Q), some parameters are needed, which are average BSC (A), accumulated average BSC (AA), and Contribution (Cont). The average BSC score for each year is gathered by using fuzzy logic. The membership function for finance, customer, business process, learning, and performance is the same. It is divided into Bad (B), Normal (N), Good (G), and Very Good (VG). The membership function can be seen in Fig. 3. For the fuzzy rules, every result with 3 VG parameters will produce VG performance, and then every result with 2 VG or 3 G parameters will result in G performance.

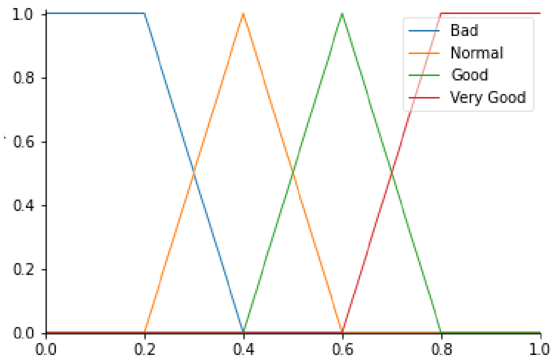

Figure 3. Fuzzy membership function.

$$AccumulateAverage(AA) = \frac{1}{n}\sum_{i=1}^{n} Ai \quad (2)$$

$$\begin{aligned} 0.00 \le \rho neu \le 0.20 \\ 0.20 < \rho temp \le 0.45 \\ 0.45 < \rho hum \le 0.70 \\ 0.70 < \rho pred \le 1.00 \end{aligned} \quad (3)$$

$$\begin{aligned} 0.00 \le \rho neu \le 0.10 \\ 0.10 < \rho temp \le 0.27 \\ 0.27 < \phi hum \le 0.44 \\ 0.44 < \rho pred \le 0.72 \\ 0.72 < \rho leaf \le 1.00 \end{aligned} \quad (4)$$

$$\text{Contribution(Cont)} = \frac{\sum_{i=1}^{n} \rho i \theta i}{\delta}. \quad (5)$$

TABLE I. AVERAGE, ACCUMULATED AVERAGE, CONTRIBUTION

Year	F	C	BP	L	A	AA	Cont
1	0.90	0.80	0.80	0.90	0.84	0.84	0.0000
2	0.90	0.80	0.70	0.80	0.82	0.83	-0.0625
3	0.80	0.70	0.90	0.90	0.82	0.83	-0.1250
4	0.70	0.70	0.80	0.80	0.72	0.80	0.1250
5	0.90	0.90	0.80	0.80	0.84	0.81	0.0194
6	0.80	0.90	0.80	0.70	0.82	0.82	-0.0100
7	0.90	0.80	0.70	0.80	0.82	0.80	-0.0100
8	0.70	0.70	0.70	0.90	0.72	0.81	0.0194
9	0.70	0.90	0.80	0.90	0.82	0.81	-0.0194
10	0.60	0.90	0.90	0.80	0.84	0.81	0.0194
11	0.90	0.80	0.90	0.70	0.82	0.81	0.0194
12	0.60	0.80	0.90	0.90	0.84	0.81	-0.0194
13	0.80	0.80	0.70	0.90	0.82	0.81	-0.0194
14	0.70	0.90	0.60	0.80	0.72	0.81	0.0000
15	0.80	0.80	0.70	0.90	0.82	0.81	-0.0100
16	0.90	0.70	0.80	0.80	0.82	0.81	0.0000
17	0.80	0.70	0.70	0.80	0.72	0.81	0.0194
18	0.70	0.80	0.80	0.80	0.82	0.81	-0.0100
19	0.90	0.70	0.80	0.70	0.72	0.80	-0.0100
20	0.90	0.80	0.90	0.80	0.84	0.80	-0.0194
21	0.90	0.80	0.80	0.70	0.82	0.80	0.0194
22	0.80	0.60	0.70	0.80	0.72	0.80	-0.0357
23	0.70	0.70	0.90	0.80	0.72	0.80	-0.0179
24	0.90	0.80	0.80	0.70	0.82	0.80	-0.0357
25	0.80	0.90	0.90	0.70	0.82	0.80	-0.0357
26	0.70	0.80	0.80	0.70	0.72	0.80	0.0000
27	0.80	0.90	0.80	0.70	0.82	0.80	-0.0179
28	0.80	0.70	0.90	0.80	0.82	0.80	-0.0179
29	0.90	0.80	0.70	0.70	0.72	0.80	-0.0179
30	0.80	0.70	0.60	0.90	0.72	0.79	0.0000
31	0.70	0.90	0.80	0.70	0.72	0.79	-0.0179

After fuzzy logic was used, the average BSC score for each year (A) was obtained. Also, the accumulated average BSC score (AA) can be calculated using Eq. (2). Besides A and AA values, external factors can give either negative or positive contributions (Cont) to the final result (Q). There are three negative contributions in the egg phase (year 1 until 4) and chrysalis phase (year 22 until 31): temperature, humidity, and predator. There is one positive contribution in the caterpillar phase (year 5 until 21): the leaf and three negative contributions are the same as the egg and chrysalis phase. In all phases, the neutral condition is a condition when all external factors do not appear. The probability of external factors happening in the egg and chrysalis phase can be seen in Eq. (3) and the caterpillar phase in Eq. (4). The contribution value can be calculated using Eq. (5) with δ equal to 4 for the egg phase, δ equal to 17 for the caterpillar phase, and δ equal to 14 for the chrysalis phase. If external factors appear, the ρ value should be set to 1; otherwise, 0. The result from A, AA, and Cont is shown in Table I.

TABLE II. COMPANY GROWTH PERFORMANCE FOR EACH YEAR

Year	F	C	BP	L	QN	QF
1	0.90	0.80	0.80	0.90	0.85	0.84
2	0.90	0.80	0.70	0.80	0.76	0.77
3	0.80	0.70	0.90	0.90	0.64	0.64
4	0.70	0.70	0.80	0.80	0.49	0.49
5	0.90	0.90	0.80	0.80	0.85	0.84
6	0.80	0.90	0.80	0.70	0.83	0.83
7	0.90	0.80	0.70	0.80	0.81	0.82
8	0.70	0.70	0.70	0.90	0.82	0.82
9	0.70	0.90	0.80	0.90	0.81	0.81
10	0.60	0.90	0.90	0.80	0.82	0.83
11	0.90	0.80	0.90	0.70	0.84	0.85
12	0.60	0.80	0.90	0.90	0.83	0.83
13	0.80	0.80	0.70	0.90	0.81	0.81
14	0.70	0.90	0.60	0.80	0.80	0.81
15	0.80	0.80	0.70	0.90	0.79	0.80
16	0.90	0.70	0.80	0.80	0.79	0.80
17	0.80	0.70	0.70	0.80	0.81	0.81
18	0.70	0.80	0.80	0.80	0.80	0.80
19	0.90	0.70	0.80	0.70	0.79	0.79
20	0.90	0.80	0.90	0.80	0.77	0.77
21	0.90	0.80	0.80	0.70	0.79	0.79
22	0.80	0.60	0.70	0.80	0.94	0.93
23	0.70	0.70	0.90	0.80	0.92	0.91
24	0.90	0.80	0.80	0.70	0.89	0.88
25	0.80	0.90	0.90	0.70	0.85	0.84
26	0.70	0.80	0.80	0.70	0.85	0.84
27	0.80	0.90	0.80	0.70	0.83	0.82
28	0.80	0.70	0.90	0.80	0.80	0.80
29	0.90	0.80	0.70	0.70	0.78	0.78
30	0.80	0.70	0.60	0.90	0.78	0.77
31	0.70	0.90	0.80	0.70	0.76	0.75

After the average BSC score (A), accumulated average BSC (AA), and contribution (Cont) were gathered, the company growth performance (Q) was calculated. It uses Eq. (5) to calculate Q for the egg phase, Eq. (6) for the caterpillar, and Eq. (7) for the chrysalis. In the chrysalis phase, Quality of Beauty (QB) is added, shown in Eq. (9), where φ denotes the quality of antennas, sucking-mouth, and beautiful wings (assumed as 1.00). The final company growth performance for the chrysalis phase is shown in Eq. (10). The exact result can be seen in Table II, comparing

BLCA without fuzzy (QN) and BLCA with fuzzy (QF). The result shows that the egg phase and chrysalis phase has a downward trend because there is only a negative contribution, while the caterpillar phase trend is more stable because it has a positive and negative contribution.

$$\mathrm{Qegg} = \mathrm{AA} + \sum_{i=1}^{n} \mathrm{Cont}_i \tag{6}$$

$$\mathrm{Qcat} = \left(\frac{\mathrm{AAegg} + \sum_{i=5}^{n} A_i}{n\text{-}4+1}\right) + \sum_{i=5}^{n} \mathrm{Cont}_i \tag{7}$$

$$\mathrm{Qchr} = \left(\frac{\mathrm{AAegg} + \mathrm{AAcat} + \sum_{i=22}^{n} A_i}{n\text{-}21+2}\right) + \sum_{i=22}^{n} \mathrm{Cont}_i \tag{8}$$

$$\mathrm{QB} = (1\text{-}\mathrm{Qcat}) \times (\phi\text{-}\sum_{i=21}^{n} \mathrm{Cont}_i) \tag{9}$$

$$\mathrm{QchrFinal} = \mathrm{Qchr} + \mathrm{QB} \tag{10}$$

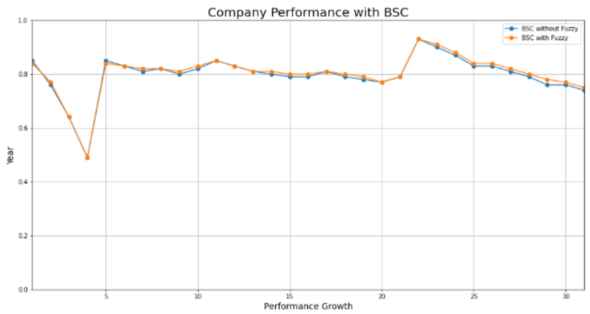

Figure 4. Result of fuzzy BLCA vs non-fuzzy BLCA.

In a previous study, the average company performance based on BSC for 14 years was 0.8604. In this study, the average company performance result for 14 years without fuzzy is 0.7825. The difference value is 0.0779 points. The vast difference comes because, in the previous study, the positive contribution value is 0.0588 (come from 1 divided by 17), which caused the most company growth performance (Q) value to be more than 1. After some analysis, it was found that the correct value for positive contribution is 0.0194 (come from 0.33 divided by 17). The graph comparing fuzzy BLCA and non-fuzzy BLCA can be seen in Fig. 4. The graph shows the result from using the correct positive contribution value.

By implementing fuzzy logic, the company’s growth performance value for 14 years was 0.7851. It is different from the previous BLCA without fuzzy, with the difference value being 0.0026. After that, the company growth performance for 31 years (until the butterfly phase) using fuzzy is 0.8024, while the value without fuzzy is 0.8029. Again, there is a difference, with a value of 0.0004. The differences between BLCA and Fuzzy-BLCA are different, but an enormous difference can be seen when comparing the model result that uses a 0.0588 contribution value with a 0.0194 contribution value.

In a mathematical format, the trendline equation for the Fuzzy BLCA result can be seen in Eq. (11), whereas the original data trend line is shown in Eq. (12). It means both patterns show the contradiction statistically.

$$y = 0.0022x + 0.7673 \tag{11}$$

$$y = \text{-}0.0004x + 0.7821 \tag{12}$$

V. Conclusion and Future Works

This paper shows the results of implementing fuzzy logic with BLCA to calculate company growth performance based on the BSC. Using fuzzy logic in the BSC can reduce bias value in the BSC parameters, leading to more precise company growth performance calculations. The difference between BLCA with fuzzy and without fuzzy are slightly different, with a value of 0.0026. A considerable difference occurs when comparing the BLCA result from a previous study that uses 0.0588 positive contributions with the result from this study that uses 0.0194 positive contributions. The difference value is 0.0779 points. This paper successfully shows the result of enhancing the previous calculation, implementing all stages of BLCA and implementing fuzzy logic.

Another improvement in the BLCA algorithm can be achieved. Such as implementing the SWOT perspective with fuzzy logic and then comparing the result with non-fuzzy BLCA based on SWOT. The limitation of this research is that the model is not tested using real-world data. Future research should be executed to implement the algorithm using real-world company data and then compare the actual condition with the model result.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

Gregoryus Imannuel Perdana and Muhammad Donny Devanda conducted the research, created, tested the algorithm, and mostly drafted papers. Ditdit Nugeraha Utama reviewed the manuscript and supervised the research. All authors had approved the final version.

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