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The Best Employee Of The Year Using Pythagorean Fuzzy Numbers

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Abstract: In the context of any jobs, employees play an important role in the development of an organization. The success of any organization is significantly dependant on the quality of their employees. Thus, employers should always ensure that their employees are motivated, hence their efforts and work performances will be optimized. Employee performance appraisal is one of the ways to motivate employees, in which employers appreciate their employees by offering promotions, introducing recognition awards such as the best employee awards or rewarding them by remuneration in forms of bonuses or yearly vacations. The process of selecting the best employee is very vital and are evaluated based on the standards criteria, sets by the company and usually made by top managements. Based on previous research, selection of the best employee of the year was usually modelled by using the analytic hierarchy process (AHP) based on crisp number. The same method is applied for this current research, but it was extended using Pythagoras Topsis (PFTOPSIS) model based on fuzzy scale. A model was developed using Analytic Pythagorean Fuzzy Number (PFN) which uses both qualitative and quantitative decision making approaches. In this approach, a score function based comparison method was proposed to identify the Pythagorean fuzzy positive ideal solution and the Pythagorean fuzzy negative ideal solution. Afterward, a revised closeness was introduced to identify the optimal alternative. This model considered 4 criteria and 22 sub-criteria to be evaluated in ranking the best employee of the year. The results show that the qualities of works contributes significantly on the evaluation of the best employee of the year.

Keywords:Best employee, Fuzzy number, Main criteria, Pythahorean Number, Sub criteria

1 Introduction

An employeer refers to any individual who was hired by an employer to do a specific job. The terms of an individual's employment are specified through mutual agreement, either verbally or written such as by offer letters or employment contracts. An employee is an important asset for an organization to help them achieve their goal and objectives. Highly motivated employees are keys to the success of an organization since motivated employees can lead to an increased productivity and allow an organization to achieve higher levels of output. Employee performance appraisal is one of the ways to motivate employees. Performance appraisal is defined as "the process of identifying, evaluating and developing the work performance of the employee in the organization, so that organizational goals and objectives are effectively achieved while, at the same time, benefiting employees in terms of recognition, receiving feedback, and offering career guidance"[1].

The selection of the best employees is one of the processes of evaluating how well the performance of the employees and are usually evaluated based on the standard criteria set by the company and usually done by top managements such as General Managers or Directors. Presently, the selection of the best employees is still performed manually, and evaluated by considering many criteria and alternatives. Therefore, the decision making by the top managerial becomes complicated, and prolonged. Therefore, it is necessary to build a more effective and reliable decision support system that can help to facilitate and assist the decision-makers in determining the best choice based on standard acceptable criteria.

The purpose of this research is to use Pythagorean Fuzzy Set (PFS) to help the employers to determine the best employee of the year.

2 Literature Review

Intuitionistic fuzzy sets, (IFS) have been introduced by Atanassov, [2] and have been used by many scholars in different fields to address uncertainty. For example, it has been used by Khaleie and Fasanghari [3] for decision-making problems in medical diagnosis, and pattern recognition. The advantage of these sets are they can be expressed in terms of membership functions, non-membership functions, and hesitancy degrees. However, in some cases, it fails to fulfill the conditions, especially when the degree of membership and non-membership is bigger than 1. Obviously, IFS is unable to capture this problem. Due to this, Yager [4] has developed Pythagorean fuzzy sets (PFSs). These sets are the improvisations to the previous IFSs, and they are more powerful and flexible tools in solving problems involving uncertainty. PFSs are clearly more suitable for real-life decision-making process.

Zhang and Xu [5] extended the technique for order preferences using the similarity to the ideal solution (TOPSIS) method to deal with multiple criteria decision making with PFS. The interactive multi-criteria decision-making (TODIM) approach has been introduced by Ren [6] to solve the MCDM problems with Pythagorean fuzzy information. Zhang [7] developed a novel Pythagorean fuzzy QUALIFLEX (qualitative flexible multiple criteria method) method based on a closeness index to deal with hierarchical multi-criteria Pythagorean fuzzy decision-making problems. In 2020, Wang [8] used Pythagorean fuzzy geometric Bonferroni mean and weighted Pythagorean fuzzy geometric Bonferroni mean operators to fuse the information in the Pythagorean fuzzy multi-criteria group decision-making problem.

Previously, the best employee of the year decision-making process was modelled by using analytic hierarchy process (AHP) [9] based on crisp number and this research was extended by using Pythagoras Topsis (PFTOPSIS) model based on fuzzy scale. A few factors used in the problem were weighted according to this model.

3. Methodology

The decision-making process to select the best employee of the year was modelled by using Pythagoras Topsis (PFTOPSIS) model. One of the latest tools used to deal with impreciseness is Pythagorean fuzzy sets. These sets generalize intuitionistic fuzzy sets with a wider scope of applications, thus make it more resourceful in tackling any decision making problems [10]. The factors in the problem were weighted according to this model. Below is the flowchart of PFTOPSIS modelling.

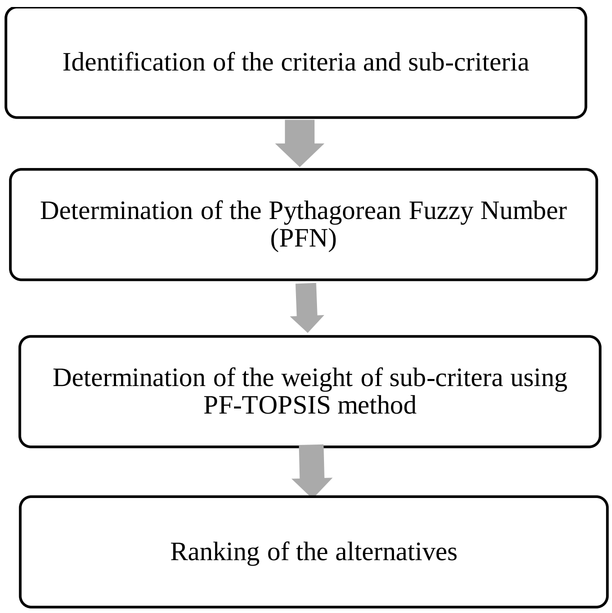

Figure 1: Flowchart of the PFTOPSIS

A Identification of the Main Criteria, Sub-Criteria and Linguistic Terms.

The full forms and necessary details of the criteria, sub-criteria and the linguistic terms that have been used in this research are shown in Table 1 and Table 2. The criteria and sub-criteria are based on the previous research [8].

Table 1: Main Criteria and Sub-Criteria

Main Criteria	Sub-Criteria
Quality of Work (QW) QW is the value of work delivered by an individual towards successfully of the organization.	- Quantity (Qu) - Quality (Ql) - Punctuality (P) - Work Effectiveness (WE) - Up to Standard (US) - Dedication (D) - Systematic (S)
Personal Quality (PQ) PQ refers to the characteristics, attributes or personality traits of a staff/worker.	- Organize (Or) - Discipline (Dc) - Competence (Ct) - Teamwork/Cooperation (TC) - Sence of Humor (SH) - Leader Instruction (LI) - Opinion/Ideas (OI) - Well Dressed (WD)
Knowledge and Skills (KS) KS refers to the knowledge and skills about the jobs/tasks/posts assigned, by a staff/worker	- Knowledge (K) - Skills (S) - Policy Implementation (PI) - Communication (CM) - Leadership (L)
External Factor (EF) EF refers to the Involvement of a staff/worker with external agencies towards the future development of the company	- Contribution to Society (CS) - Involvement of the Non-Organizational Activity (IN)

Table 2: Linguistic Terms and The Corresponding Pythagorean Fuzzy Numbers

Linguistic terms	Rating scale in crisp number	Pythagorean fuzzy scale
Very low influence	0	(0,0)
Low influence	1	(0.1,0.9)
Medium low influence	2	(0.2,0.9)
Medium influence	3	(0.4,0.6)
Medium high influence	4	(0.5,0.7)
High influence	5	(0.7,0.2)
Very high influence	6	(0.9,0.1)

B Calculation of the weight of the main criteria

The table below shows the pairwise comparison of the main criteria. The weight of the main criteria was calculated by using Analytic Hierarchy Process (AHP) method with Pythagorean Fuzzy Numbers, and the weight of each criterion is shown in Table 4.

Table 3: The Pairwise Comparison of Main Criteria

Criteria	EF	KS	PQ	QW
EF	(1,1)	(0.4,0.6)	(0.5,0.7)	(0.7,0.2)
KS	(1/0.4,1/0.6)	(1,1)	(0.4,0.6)	(0.5,0.7)
PQ	(1/0.5,1/0.7)	(1/0.4,1/0.6)	(1,1)	(0.4,0.6)

QW	(1/0.7,1/0.2)	(1/0.5,1/0.7)	(1/0.4,1/0.6)	(1,1)

Table 4: The Weight of The Main Criteria.

Main Criteria	Weightage
Quality of Work (QW)	0.4026106
Personal Quality (PQ)	0.2627263
Knowledge and Skills (KS)	0.2023279
External Factor (EF)	0.1323352

C Determination of the weight of sub-critera using PF-TOPSIS method

In this section, the weight of sub-criteria using PF-TOPSIS method was calculated based on the data collected from ten employees of Amir Technology Sdn Bhd as survey samples. There were five steps involved in this process.

i. Determination of decision matrix.

Table 5-8 shows the decision matrix of each criteria based on sub criteria. The decision matrix of each employee is based on survey.

Table 5: Pythagorean fuzzy number-based decision matrix for quality of work (QW)

	Ql	Qu	P	W	S	D	US
Employee 1	(0.7,0.2)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 2	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 3	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.9,0.1)	(0.9,0.1)	(0.9,0.1)	(0.7,0.2)
Employee 4	(0.7,0.2)	(0.9,0.1)	(0.9,0.1)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 5	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 6	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 7	(0.4,0.6)	(0.5,0.7)	(0.5,0.7)	(0.4,0.6)	(0.1,0.9)	(0.5,0.7)	(0.7,0.2)
Employee 8	(0.5,0.7)	(0.7,0.2)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 9	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 10	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.9,0.1)	(0.9,0.1)

Table 6: Pythagorean Fuzzy Number-Based Decision Matrix for Personal Quality (PQ)

	Or	Dc	Ct	TC	SH	LI	OI	WD
Employee 1	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.9,0.1)	(0.5,0.7)	(0.7,0.2)	(0.5,0.7)
Employee 2	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 3	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)
Employee 4	(0.9,0.1)	(0.9,0.1)	(0.9,0.1)	(0.9,0.1)	(0.7,0.2)	(0.9,0.1)	(0.7,0.2)	(0.4,0.6)
Employee 5	(0.7,0.2)	(0.9,0.1)	(0.7,0.2)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 6	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 7	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.4,0.6)
Employee 8	(0.5,0.7)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.5,0.7)	(0.7,0.2)
Employee 9	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 10	(0.7,0.2)	(0.9,0.1)	(0.9,0.1)	(0.7,0.2)	(0.4,0.6)	(0.5,0.7)	(0.5,0.7)	(0.5,0.7)

Table 7: Pythagorean Fuzzy Number-Based Decision Matrix for Knowledge and Skills (KS)

	K	SK	PI	CM	L
Employee 1	(0.9,0.1)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 2	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 3	(0.9,0.1)	(0.9,0.1)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 4	(0.9,0.1)	(0.9,0.1)	(0.5,0.7)	(0.7,0.2)	(0.9,0.1)
Employee 5	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 6	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 7	(0.5,0.7)	(0.4,0.6)	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)
Employee 8	(0.9,0.1)	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)
Employee 9	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)	(0.7,0.2)
Employee 10	(0.5,0.7)	(0.5,0.7)	(0.7,0.2)	(0.7,0.2)	(0.5,0.7)

Table 8: Pythagorean Fuzzy Number-Based Decision Matrix for External Factor (EF)

	CS	IN
Employee 1	(0.9,0.1)	(0.9,0.1)
Employee 2	(0.7,0.2)	(0.5,0.7)
Employee 3	(0.7,0.2)	(0.7,0.2)
Employee 4	(0.5,0.7)	(0.4,0.6)
Employee 5	(0.7,0.2)	(0.7,0.2)
Employee 6	(0.7,0.2)	(0.5,0.7)
Employee 7	(0.5,0.7)	(0.4,0.6)
Employee 8	(0.7,0.2)	(0.7,0.2)
Employee 9	(0.7,0.2)	(0.7,0.2)
Employee 10	(0.5,0.7)	(0.5,0.7)

ii.Calculation of the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS)

Table 9 – 12 shows the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) of each criteria based on sub criteria using Eq. (1) and (2) below:

$$x^{+} = \left\{C_j, max\langle s(C_j(x_i))\rangle \middle| j = 1,2,\ldots,n\right\}$$
$$= \{\langle C_1, P(u_1^{+}, v_1^{+})\rangle, \langle C_2, P(u_2^{+}, v_2^{+})\rangle, \ldots, \langle C_n, P(u_n^{+}, v_n^{+})\rangle\} \quad (1)$$
$$x^{-} = \left\{C_j, min\langle s(C_j(x_i))\rangle \middle| j = 1,2,\ldots,n\right\}$$
$$= \{\langle C_1, P(u_1^{-}, v_1^{-})\rangle, \langle C_2, P(u_2^{-}, v_2^{-})\rangle, \ldots, \langle C_n, P(u_n^{-}, v_n^{-})\rangle\} \quad (2)$$

Table 9: FPIS and FNIS of Quality of Work

Sub-criteria	A+	A-
Ql	(1,0.2857)	(0.5713,0.8573)
Qu	(1,0.1112)	(0.5556,0.7778)
P	(1,0.1112)	(0.5556,0.7778)
W	(1,0.1112)	(0.4444,0.6669)
S	(1,0.1112)	(0.1112,1)
D	(1,0.1112)	(0.5556,0.7778)
US	(1,0.1112)	(0.7778,0.2222)

Table 10: FPIS and FNIS of Personal Quality

Sub-criteria	A+	A-
Or	(1,0.1112)	(0.5556,0.7776)

Dc	(1,0.1112)	(0.5556,0.7776)
Ct	(1,0.1112)	(0.7776,0.2220)
TC	(1,0.1112)	(0.5556,0.7776)
SH	(1,0.1112)	(0.4444,0.6664)
LI	(1,0.1112)	(0.5556,0.7776)
OI	(1,0.2855)	(0.7145,1)
WD	(1,0.2855)	(0.5715,0.8570)

Table 11: FPIS and FNIS of Knowledge and Skills

Sub-criteria	A+	A-
K	(1,0.1110)	(0.5560,0.7780)
SK	(1,0.1110)	(0.4451,0.6670)
PI	(1,0.2860)	(0.7147,1)
CM	(1,0.2860)	(0.7147,1)
LI	(1,0.1110)	(0.5560,0.7780)

Table 12: FPIS and FNIS of External Factor

Sub-criteria	A+	A-
CS	(1,0.1108)	(0.5558,0.7775)
IN	(1,0.1108)	(0.4442,0.6667)

iii. Determination of the distance between two fuzzy numbers.

Table 13- Table 16 shows the distance between two fuzzy numbers based on criteria and sub-criteria. The distances from Pythagorean fuzzy PIS and NIS were determined using Eq.(3) as follows:

$$d(x,y) = \sqrt{1/2[(a_1 - a_2)^2 + (b_1 - b_2)^2)]} \quad (3)$$

Table 13: Distance between Two Fuzzy Number of Quality of Work

Employee	d+(x,y)	d-(x,y)
Employee 1	0.878	3.0352
Employee 2	1.5976	2.5295
Employee 3	0.5268	3.3624
Employee 4	0.5268	3.3413
Employee 5	1.5976	2.5295
Employee 6	1.5976	2.5295
Employee 7	3.8248	0
Employee 8	1.422	2.6729
Employee 9	1.0536	2.8918
Employee 10	1.6373	2.4254

Table 14: Distance between Two Fuzzy Number of Personal Quality

Employee	d+(x,y)	d-(x,y)
Employee 1	2.5947	1.6656
Employee 2	1.0542	3.1344
Employee 3	1.8356	2.4297
Employee 4	0.6808	3.3782
Employee 5	0.7028	3.421
Employee 6	1.0542	3.1344
Employee 7	2.7314	1.5015
Employee 8	1.8133	2.3105
Employee 9	1.0542	3.1344
Employee 10	2.5614	1.7313

Table 15: Distance between Two Fuzzy Number of Knowledge and Skills

Employee	d+(x,y)	d-(x,y)

Employee 1	0.1757	2.6325
Employee 2	0.5271	2.3261
Employee 3	0.1757	2.6325
Employee 4	0.5437	2.2324
Employee 5	0.5271	2.3261
Employee 6	0.5271	2.3261
Employee 7	2.3852	0.423
Employee 8	1.286	1.6443
Employee 9	0.5271	2.3261
Employee 10	1.6998	1.1984

Table 16: Distance between Two Fuzzy Number of External Factors

Employee	d+(x,y)	d-(x,y)
Employee 1	0	1.1224
Employee 2	0.7425	0.5338
Employee 3	0.352	0.8153
Employee 4	1.1224	0
Employee 5	0.352	0.8153
Employee 6	0.7425	0.5338
Employee 7	1.1224	0
Employee 8	0.352	0.8153
Employee 9	0.352	0.8153
Employee 10	1.133	0.1112

iv. The distance from each alternative to the FPIS

Table 17 and Table 18 below shows the distance from each alternative to the FPIS and FNIS. The distance from each alternative to the FPIS and to the FNIS were determined using Eq.(4) and (5) as follows:

$$d_i^* = \sum_{j=1}^{n} d(v_{ij,} v_j^*) \quad (4)$$

$$d_i^- = \sum_{j=1}^{n} d(v_{ij,} v_j^-) \quad (5)$$

Table 17: The distance from each alternative to the FPIS

	QW	PQ	K	EF	d_i^*
Employee 1	0.878	2.5947	0.1757	0	3.6484
Employee 2	1.5976	1.0542	0.5271	0.7425	3.9214
Employee 3	0.5268	1.8356	0.1757	0.352	2.8901
Employee 4	0.5268	0.6808	0.5437	1.1224	2.8737
Employee 5	1.5976	0.7028	0.5271	0.352	3.1795
Employee 6	1.5976	1.0542	0.5271	0.7425	3.9214
Employee 7	3.8248	2.7314	2.3852	1.1224	10.0638
Employee 8	1.422	1.8133	1.286	0.352	4.8733
Employee 9	1.0536	1.0542	0.5271	0.352	2.9869
Employee 10	1.6373	2.5614	1.6998	1.133	7.0315

Table 18: The distance from each alternative to the FNIS

	QW	PQ	K	EF	d_i^-
Employee 1	3.0352	1.6656	2.6325	1.1224	8.4557
Employee 2	2.5295	3.1344	2.3261	0.5338	8.5238

Employee 3	3.3624	2.4297	2.6325	0.8153	9.2399
Employee 4	3.3413	3.3782	2.2324	0	8.9519
Employee 5	2.5295	3.421	2.3261	0.8153	9.0919
Employee 6	2.5295	3.1344	2.3261	0.5338	8.5238
Employee 7	0	1.5015	0.423	0	1.9245
Employee 8	2.6729	2.3105	1.6443	0.8153	7.443
Employee 9	2.8918	3.1344	2.3261	0.8153	9.1676
Employee 10	2.4254	1.7313	1.1984	0.1112	5.4663

v. Compute the closeness coefficient cci for each alternative

Table 19 show the closeness coefficient for each alternative using Eq.(6) as follows:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*} \quad (6)$$

Table 19: The closeness coefficient CC_i for each alternative

Candidate	d_i^*	d_i^-	CC_i
Employee 1	3.6484	8.4557	0.6989
Employee 2	3.9214	8.5238	0.6849
Employee 3	2.8901	9.2399	0.7617
Employee 4	2.8737	8.9519	0.7808
Employee 5	3.1795	9.0919	0.7409
Employee 6	3.9214	8.5238	0.6849
Employee 7	10.0638	1.9245	0.1605
Employee 8	4.8733	7.443	0.6043
Employee 9	2.9869	9.1676	0.7543
Employee 10	7.0315	5.4663	0.4374

3 Result and Discussion

This research was conducted to propose a reliable and practical selection method to find the best employee of the year for an organization, to substitute the current manual process which is tedious and complicated. The selection was made by evaluating the employee's performances based on the criteria and sub-criteria chosen. Based on the results, these criteria contribute differently to the rank, and can be categorized as 'very low influence' to 'very high influence'. Prior to the research, a preliminary survey was carried out to test the effectiveness of the method. Table 20 shows the rank of each employee. The ranking is based on the value of the closeness coefficient with the greatest value placed at the top.

Table 20: Ranking of Employee

Candidates	**Total Final Weightage (Overall)**	**Rankings**
Employee 4	0.7808	1
Employee 3	0.7617	2

Employee 10	0.7543	3
Employee 8	0.7409	4
Employee 9	0.6989	5
Employee 5	0.6849	6
Employee 6	0.6849	7
Employee 2	0.6043	8
Employee 1	0.4374	9
Employee 7	0.1605	10

Based on the greatest value of QW and PQ, E4 was the most qualified employee to be awarded as the best employee of the year, followed by E3, contributed by the highest priority value of QW and KS. Even though E3 has the highest priority for two criteria, E4 is still in the first rank, since PQ is categorized to be more influenced characteristic or factors ('very high influence') as compared to the knowledge and skills.

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