Performance Evaluation by Means of Fuzzy Mathematics. The Case of a Clinical Laboratory

Noel Varela Izquierdo[a], Amelec Viloria[b], Omar Bonerge Pineda Lezama[c], Mercedes Gaitán-Angulo[d], Hernán Hernández Herrera[e]

[a,b,e]*Universidad de la Costa, Programa de Ingeniería Industrial, Barranquilla, Colombia. Email:* [a]*nvarela2@cuc.edu.co;* [b]*aviloria7@ cuc.edu.co,* [e]*hhernand16@cuc.edu.co*
[c]*Universidad Tecnológica Centroamericana (UNITEC), Honduras: omarpineda@unitec.edu*
[d]*Corporación Universitaria Empresarial de Salamanca (CUES), Barranquilla, Colombia. Email: m_gaitan689@cues.edu.co*

Abstract: This paper presents the implementation of a performance evaluation procedure (PD) supported by quantitative techniques, using diffuse mathematics to reduce uncertainty. Is applies to a process key of a laboratory clinical, obtaining is a model that based its evaluation in indicators of performance related with them objectives of the company, allowing to the evaluator an alternative clear in the definition of criteria, in the weighting of each one of them and in the analysis of each result, decreasing its uncertainty for be used as tool of management and takes of decisions.

Keyword: Evaluation, Performance, Fuzzy Mathematics.

1. INTRODUCTION

The human resources (HR) management models focuses in the improvement of companies' results froma human resource perspective ([1], [2]). One main approach to this end is the assessment of the HR performance to maintain or improve the quality and productivity standards required for a higher competitiveness. Some approaches have been developed, including the competency-based HR evaluation [3] and the graphic scales-based evaluation [4].

The MEG establish practices of human resources management aimed at improving the attitude and behavior of employees at work, as well as the necessary knowledge and abilities to establish 'good management practices' ([5], [6], [7]). High Commitment Human Resources Management Systems (SAC) are in general adequate in a context of quality management and for the adoption of a model of excellence in particular, ([8]; [6]; [9]; [10]).

While SACs include practices of assessment of performance and remuneration based on work efficiency [11], part of the literature about quality management (QMS) [12] do not consider them adequate to promote attitudes and behavior based on collaboration and team work, necessary in the frame of a QMS initiative. In fact,

[13], [14], [15], [16] consider that a non-solved problem in QMS literature is the analysis of the characteristics that a performance evaluation system should have, which is still a subject under debate.

Many organizations or companies carry out informal evaluations of work performance based on employees' daily work. These assessment are insufficient for a correct performance evaluation and therefore, to achieve the goals set by organizations. Consequently, they have been gradually introducing different methods of PE, achieving in that way an efficacious tool for the direction of policies and measures that improve output.

The application of fuzzy logic in PE has been studied by several researchers, especially in the Asia-Pacific region. Among the authors stand out: [17], [18], [19], [20], [21], [22], [23] and [24].

In the aspect related with the application of the mathematical diffuse to the evaluation of the performance, it bibliography is more scarce, [25] develop a research where apply it mathematical diffuse to a model comparative between them models of evaluation individual and it evaluation collective of the process to belongs, where defend it theory of that them systems of evaluation of the performance individual they must integrate collective indicators.

The purpose of the present work is to apply a procedure that allows to incorporate to the performance evaluation the method of graphic scales using diffuse mathematics on a key process of a clinical laboratory.

2.   MATERIALS AND METHODS

This section establishes the methodology of performance evaluation and the procedure to incorporate the diffuse mathematics to it. The object of study is a clinical laboratory.

(a) Study Object (Clinical Laboratory)

A clinical laboratory in Honduras was selected, certified by ISO 9001: 2008, which has 8 branches, more than 90 employees and an implemented process management system.

The three processes key of the Organization are which you provide the value added to the company and are the following: process pre-analytical (includes, the reception and takes of shows to them customers), the process analytical (includes all the analysis chemical and biological and validation of them samples taken) and the process post-analytical (includes the elaboration and sent of them results to them customers)

The PE that applied was the traditional, did so once a year based on organizational objectives in the long term, and with a high subjectivity in its indicators, where each functional area manager, evaluated their employees by the results of the process indicators, including les elements associated with their behavior.

Starting of the mapping general of your organization is proposed that each process organizational (key, of support and strategic) designed their indicators general and specific to be evaluated, linking them directly with them objectives of its planning strategic.

(b) Performance Evaluation Methodology

On the basis of the methodological procedure defined by [26], it is designed and implemented a system of performance evaluation that responds to the demands of the management of human resources, especially at the levels of quality and efficiency required by the development of organizations.

The procedure consists of eight stages as shown in [26]:

1. Diagnosis of the current situation of human resources.

2. Objectives of ED

3. Process requirements

4. General Model of ED

5. Performance Indicators

6. ED method

7. Determination of audit indicators

8. Implementation of the system

To design them indicators general, specific and their degrees, is uses a technical of work in group (Method Delphy) and packages statistical to define the weight specific that has each indicator depending on the importance that is attributed to the same, using for this the technical of comparison paired or nesting. [27].

(c) Fuzzy Mathematics Application Methodology for Performance Assessment

Diagnosis of the human resources of the laboratory clinical, shows an area of opportunity in the performance evaluation, the method scales graphics weighted with fuzzy math, allowed, each indicator to assess objectively, shorten assessment times, linking the results to incentive systems and increase efficiency and effectiveness indicators in each of the processes mapped in the organization. Therefore also defined the objectives of the evaluation and the demands of the process of performance evaluation, ensuring objectivity, bias and an excellent automated communication system.

After defined the model, are designed graphic scales for jobs that include the general indicators, specific, and the establishment of levels of importance of each indicator and its processes. The Delphy method by rounds, was applied to this determining 7 experts in the organization who had competition expert ¨K¨ coefficient above 0.8 (as [28]) defining the specific weight and importance of each indicator for each process. Later was developed into mathematical model on the basis of fuzzy logic [29] for the processing of the data and the results.

Subsequently it was elaborated in mathematical model based on the fuzzy logic [29] for the processing of the data and obtaining the resultsThe fuzzy inference systems according to ([25], [29]) are expert systems with approximate reasoning that map an input vector to a single (scalar) output. They are based on the fuzzy logic to make this mapping and consists of three stages: Fuzzing, Fuzzy Inference and Defuzzing.

3.   RESULTS

To show the results of the model, we took an evaluation of the individual performance as a reference, based on the graphic scale design used in the area of analytical processes (see Table 1).

The Table shows the measurement scale for that job, which includes the three general indicators (Discipline, Quality and Results), their specific indicators, the specific importance weight of each indicator, as well as levels (Bad, Regular, Good, and Excellent).

For each indicator is shows the conceptualization (What evaluates?) and the form of measurement for each one of them (How measure it?). This aspect is extremely important because helps to parameterize each indicator and make it more objective.

Table 1
Weighted evaluation scale graphic

Weighing	Weight (%)	Indicator	Bad	Regular	Good	Excellent	Conceptualization or characterization (What each evaluates?)	How to measure it?
					Results			
50%	40%	Number of patients attended	Less than 80%	Between 80% and 89%	Between 90% and 100%	> 100%	It's the amount of patients attended per branch in the month.	# of pa attended/monthly plan * 100
	30%	Sampling service supervision	>6	4.0-6.0	1.0-3.0	0	Checklist completion for area supervision	Evaluated by the number of non-completed aspects defined in the checklist area
	30%	Client satisfaction	Less than 85%	85%-90%	90%-93%	More than 93%	Parameters evaluated by the patients & clients survey.	Results of the client patient survey
					Quality			
30%	60%	Critical complaints external/internal client	>2	2	1	0	Complaints included in the satisfaction evaluation procedure	Number of complaints received each month
	20%	Biosecurity control breaches	>8	6 to 8	2 to 5	Less than 2	Adequate condition maintenance for the preservation of materials, equipment and others.	Measured through the amount of non-conforming answers to the Pre Analytical Supervision Format/Biosecurity
	20%	Registry control	>2	2	1	0	Number of failures found in the registry formats	Using the checklist per area of the number of failures found in each registry
					Discipline			
20%	30%	Image and clothes	>2	2	1	0	Dress code, reference	Number of times the dress code was not followed
	20%	Justified absences	>1	N/A	1	0	Permission or leave of absences	Number of absences reported in the absence report
	30%	Permission requests	>3	2 to 3	1	0		
	20%	Attendance and punctuality	>3	2 to 3	1	0	Measured through clock dialing	Through the punctuality report.

When applying the fuzzy evaluation model to the previous graphic, the evaluator defines for each indicator the qualitative evaluation (levels) obtained by each person evaluated. This evaluation assumes a fuzzy triangular number that is multiplied by the specific weight of each indicator, obtaining a fuzzy global result. Subsequently, the process of Defuzzing is performed using the centroid method, where each evaluated person receives a qualitative evaluation according to the levels assumed (Bad, Regular, Good, Excellent) and a quantitative defuzzied evaluation that moves between 0 and 1 (See Figure 1), this value allows an analysis of their results and comparative behavior both individually and collectively with their area and organization.
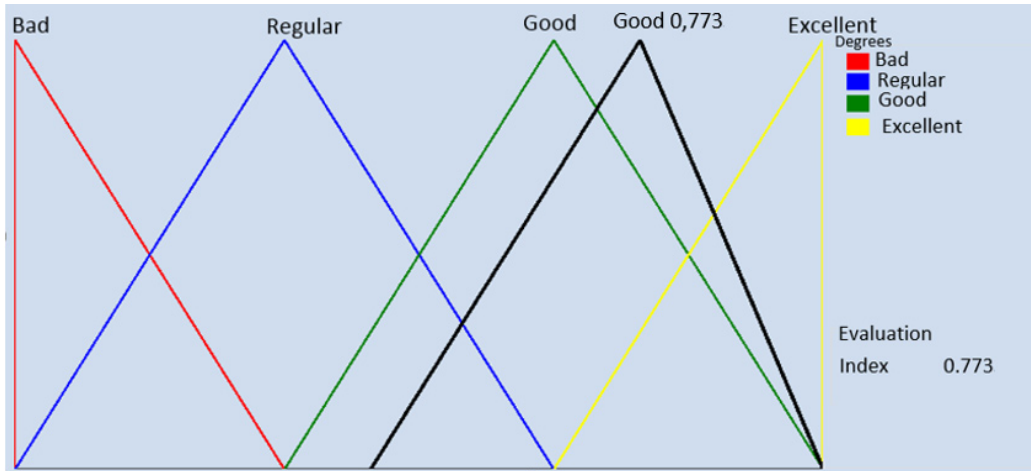
Figure 1: Defuzzied evaluation result

The final result for each employee is shown in the black triangle, this employee obtained a performance index of 0.773 placing them on a good level in their total performance. It is important to emphasize that each company can establish the standard values for each qualitative and quantitative evaluation obtained, that is to say that the company designs and establishes the evaluation policy for its results and assigns it in the rules of Defuzzing.

Finally, a very important aspect in performance evaluation is its subsequent analysis for decision making. The model allows for the observation of individual and collective behavior of the results accumulated, so as to allow more objective conclusions to be drawn for decision making. Figure 2 shows the historical behavior of the last 9 evaluations of this employee and his/her individual behavior, comparing it with the goal performance index (0.75) established by the organization.
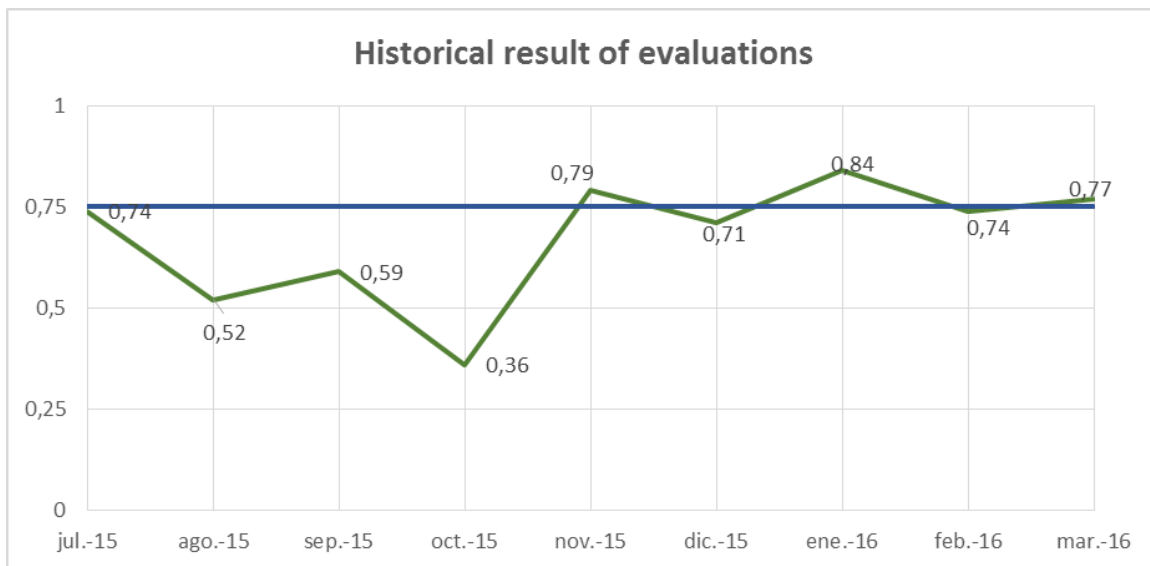

Figure 2: Historical result of the last 9 evaluations

Comparative results for the analytical area before and after the applied method: For this analysis we took the results of the management processes indicators already defined in the organization that intervene directly in the individual evaluation of the employees. They are taken as reference three months before applying the evaluation method and three months later. The results are shown in the following Table 2:

Table 2
Comparative results between both periods

Management Indicators	U/M	Before the PA			After the PA		
		June	July	August	Sept.	Octob.	Nov.
Number of Patients attended	%	96	95	96	99	102	105
Critical Clients Complaints	%	0.36	0.37	0.36	0.23	0.21	0.17
Clients Satisfaction	%	99.1	99	98.9	99.3	99.4	99.4
Process failures	%	1.2	1.3	1.2	0.8	0.8	0.7
Delivery in time of results	%	93.1	92.5	93	96.4	96.9	97.3

The Table 2 shows a behavior positive of them indicators of Management improving substantially them indicators of efficiency and effectiveness of the process analytical and demonstrating that the assessment impacts positively in such results.

It is important to highlight that already, automated procedure, allows for a qualitative and quantitative value every employee and make a rigorous management that among other advantages are the following:

- Obtaining a tangible and objective evaluation of each employee

- Showing the historical behavior of each employee.

- Comparing this behavior with the average of the department and company.

- Analyzing the results by department, jobs or company.

- Using your database to filter all information and use it in decision making (For training, risk analysis, selection, etc.).

4.   CONCLUSION

This shows the application of a performance evaluation method with a multicriteria support variant with diffuse mathematics, which reduces the uncertainty of the evaluation when subjective indicators are measured.

The results of the performance evaluation demonstrate the correct development of the implementation process system and the great advantages it offers, used as an instrument for management, control and decision making in the organization.

REFERENCES

[1]   Cuesta, A., Tecnología de Gestión de Recursos Humanos (Tercera Edición), La Habana, Editorial Félix Varela, 2010, ISBN 9789590713415.

[2]   Carreón, F. Á., Figueroa, E. G., & Montoya, D. A. (2014). El capital humano vs rentabilidad. INCEPTUM Revista de Investigación en Ciencias de la Administración, 4(7), 55-74.

[3]   Gallego, M. (2012). Gestión humana basada en competencias contribución efectiva al logro de los objetivos organizacionales. Revista universidad EAFIT,36(119), 63-71.

[4]   Varela, N, y otros. (2013) Diseño de un sistema de evaluación del desempeño al personal de ventas de Simplex Group. Revista Innovare. Laureate International Universities. Vol.2 No.2. ISSN. 2310-290X.

[5]   Ooi, K.B.; Bakar, N.A.; Arumugam, V.; Vellapan, L. & Loke, L.K. (2007), "Does TQM influence employees' job satisfaction? An empirical case analysis", International Journal of Quality & Reliability Management, 24 (1), 62-77.

[6]   Bayo, A., & Merino, J. (2001). Quality management and high performance work practices: Do they coexist? International Journal of Production Economics, 73 (3), 251-259.

[7] Escrig, A. B., & de Menezes, L. M. (2015). What characterizes leading companies within business excellence models? An analysis of "EFQM Recognized for Excellence" recipients in Spain. International Journal of Production Economics, 169, 362-375.

[8] Simmons, D.E.; Shadur, M.A. & Preston, A.P. (1995). Integrating TQM and HRM. Employee Relations, 17 (3), 75-86.

[9] Wickramasinghe, V. & Anuradha, G. (2011). High-involvement work practices, quality results, and the role of HR function: an exploratory study of manufacturing firms in Sri Lanka. The TQM Journal , 23 (5), 516-530.

[10] Alfalla, R., Marín, J. A., & Medina, C. (2012). Is worker commitment necessary for achieving competitive advantage and customer satisfaction when companies use HRM and TQM practices? Universial Business Review, (36), 64-89.

[11] Huselid, M. A. (1995). The impact of human resource management practices on turnover, productivity, and corporate financial performance. Academy of Management Journal, 38, 635-672.

[12] Deming, E. (1986). Out of the Crisis. Quality, Productivity and Competitive Position. Cambride University Press.

[13] Soltani, E., van der Meer, R., Gennard, J. & Williams, M., (2004). Case study: Have TQM organisations adjusted their performance management (appraisal) systems? A study of UKbased TQM-driven organizations. The TQM Magazine, 16 (6), 403-417.

[14] Soltani, E., van der Meer, R.; Williams, M. & Lai, P. (2006). The compatibility of performance appraisal systems with TQM, principles – evidence from current practice. International Journal of Operations & Production Management, 26 (1), 92-112.

[15] Jiménez, D., & Martínez, M. (2009). The performance effect of HRM and TQM: a study in Spanish organizations. International Journal of Operations & Production Management, 29(12), 1266-1289.

[16] Curbelo-Martínez, D., Pérez-de-Armas, M., & Varela-Izquierdo, N. (2011). Diseño y aplicación de un instrumento para la evaluación del contexto de aprendizaje en organizaciones de avanzada del territorio de cienfuegos/. Ingeniería Industrial, 32(2), 123-131.

[17] Lau, H.; Pang, W.; Wong, C. (2002) Methodology for monitoring supply chain performance: a fuzzy logic approach. Logistics Information Management. Vol. 15, N° 4:271 – 280.

[18] Ling, C., Chiu, H., Tseng, Y (2006). Agility evaluation using fuzzy logic. International Journal of Production Economics, Vol. 101:353 – 368.

[19] Silva, C.; Sousa, J.; Runkler, T. (2007) Optimization of logistic systems using fuzzy weighted aggregation. Fuzzy Sets and Systems, Vol. 158: 1947 – 1960.

[20] Arango, M.D.; Zapata, J; Adarme, A. (2010). Gestión de cadena de abastecimiento con indicadores bajo incertidumbre caso aplicado al sector panificador. Revista ciencia e ingeniería Neogranadina. Vol. 20, N° 1: 97-116.

[21] Amelec Jesus Viloria Silva (2015), "Increased Efficiency in a Company of Development of Technological Solutions in the Areas Commercial and of Consultancy" . En: Estados Unidos Adv Sci Lett ISSN: 1936-6612 ed: American Scientific Publishers. v.21 fasc.5 p.1406 – 1408.

[22] Sueldo, C. S., Urrutia, S., Paravié, D., Rohvein, C., & Corres, G. (2014). Una propuesta metodológica para la determinación de capacidades estratégicas en pymes industriales. INGE CUC, 10(2), 43-50.

[23] Predictions for 2016: A Bold New World of Talent, Learning, Leadership, and HR Technology Ahead de Bersin by Deloitte. http://www2.deloitte.com/content/dam/Deloitte/at/Documents/human-capital/bersin-predictions-2016.pdf

[24] Rockwell, E. (2015). Contradicciones de la evaluación del desempeño docente: lo que muestra la evidencia cuantitativa. Educación, Formación e Investigación., 1(1).

[25] Sampaio, P., Saraiva, P., & Monteiro, A. (2012). A comparison and usage overview of business excellence models. The TQM Journal, 24(2), 181-200.

[26] Varela Izquierdo, N. (2001). Gestión Turística. Perfeccionamiento de los Recursos Humanos en el sector hotelero (Doctoral dissertation, Tesis en opción al grado científico de Doctor en Ciencias Técnicas. Instituto Superior Politécnico "José Antonio Echevarria". Ciudad de la Habana, Cuba).

[27] Comas, A. S., Rodado, D. N., & Eras, J. C. (2016). Marcos aplicados a la Gestión de Calidad–Una Revisión Sistemática de la Literatura. Espacios, 37(09).

[28] Toro, B. V., Gazabón, D. O., Perez, D. M., & Escorcia, S. D. L. H. (2016). Factores que inciden en el desempeño eficiente de una Oficina de Transferencia de Resultados de Investigación (OTRI): Caso Cientech. Revista ESPACIOS| Vol. 37 (Nº 09) Año 2016.

[29] Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8, 338-353.