PROPOSAL FOR THE SELECTION OF EXPERTS

Mauro Patricio Andrade Romero
Email: maurop.andrade@espoch.edu.ec
ORCID:0000-0003-4805-3315
Escuela Superior Politécnica de Chimborazo.

Rafael Humberto Soler González
Email: rsoler@ucf.edu.cu
ORCID: 0000-0002-1845-6626
Universidad de Cienfuegos.

Raúl Vicente Andrade Merino.
Email: r_andrade@espoch.edu.ec
ORCID: 0000-0003-3577-6258
Escuela Superior Politécnica de Chimborazo.

Juan Francisco Dillon Gallegos
Email: juanfa_9@hotmail.com
ORCID: 0000-0002-3664-7901
Investigador Industrias Dillon Gallegos. INDIGA. S.A.S.

Abstract
The objective of this article is to propose a way to select experts and to explain conceptually the use of the tools used. The article clarifies the use of different methods for calculating the number of experts and their subsequent selection. For this purpose, a conceptual explanation of each method is given. To enhance the work presented, dissimilar practical experiences used by the authors in their profession were used. Techniques related to statistics and fuzzy logic are presented and used, and finally, a method called SG, which has been used in different research works, is proposed.

Keywords: Expert Selection Methods; Fuzzification; Relative Distances

Resumen
El objetivo de este artículo es proponer una forma de seleccionar los expertos y explicar conceptualmente el uso de las herramientas utilizadas. El artículo esclarece el uso diferentes métodos paracálculo de la cantidad de expertos y su posterior selección. Para tal efecto se hace una explicación conceptual de cada método. Se utilizaron para abundar el trabajo expuesto, disímiles experiencias prácticas utilizadas por los autores en el ejercicio de su profesión. Se exponen y se utilizan técnicas relacionada a la estadística y a la lógica difusa y finalmente se propone un método denominado SG que ha sido utilizado en diferentes trabajos investigativos.

Palabras claves: Métodos de Selección de Expertos; Fuzzificación; Distancias Relativas

Introduction

Among the tools used for developing research is the selection of experts, where different techniques based on statistical methods and other criteria quantify a series of variables that finally obtain a solution with different degrees of vagueness that propitiate the selection of competent personnel. It should be noted that the selection of experts comprises two stages: a) selecting the number of experts and b) selecting the number of experts based on the required competencies. Finally, the opinion of the experts is used to determine to what extent the results and appraisals are favorable, and for this purpose, different statistics are used to test the consistency of the appraisals.

The use of the expert method has its beginnings in two facts related to the social sphere. First, it was in the military field that a Delphi study was carried out for the first time in 1950 by the RAND Corporation for the United States Air Force, in which experts were consulted for the selection of an American industrial system and the estimation of the number of "A-bombs" required to reduce the production of ammunition to a certain amount, considering the supposed strategic planning point of view of the Union of Soviet Socialist Republics (USSR). Achieving this goal in any other way would have resulted in a practically prohibitive process. Second, the use of the coefficient of expert competence dates back to work on prospective studies of economic sciences approved in the 1970s by the State Committee for Science and Technology of the USSR(Cruz Rodriguez, 2020, p. 2).

Generally, the selection of experts follows a series of steps shown in Figure 1.

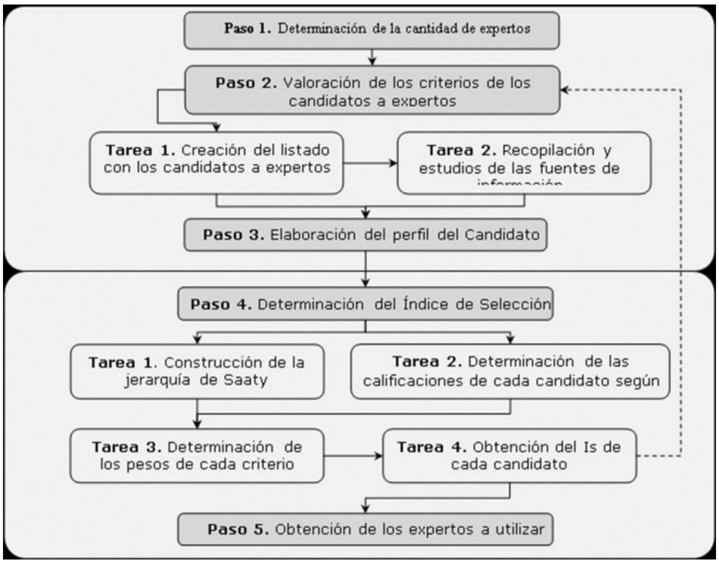


Figure 1. Steps for the selection of experts.
Source:Lao-León et al.(2016).

It should be clarified that an expert is considered one whose prior training and experience have enabled them to achieve mastery over subject matter that exceeds the average level of their peers and who is in a position to present their opinions on that subject matter for use as conclusive judgments (Hardy et al., 2015).

An expert is a person endowed with updated knowledge and skills that condition a high level of professional competence to provide evaluative criteria on a given subject or topic; in other words, a person who is recognized as having an extraordinary ability in a certain area of knowledge(Font Landa, 2012).

There are dissimilar concepts related to experts, and all of them are related to the sense that they are people with knowledge of specific topics that exceed the average of their peers, i.e., they are knowledgeable about specific topics and are intellectually more prepared than the average of the population.

There are different methods to determine the experts, but these actions have two fundamental steps: a) selection of the number of experts and b) selection of the experts from the number previously indicated. Different authors expose some principles for the selection of experts:

Before proposing the group work, the main executor, facilitator or group leader must study the universe of expert candidates related to the topic to be analyzed and, based on this, select the most promising ones that can be considered experts (Fernández Garcia & García Abreu, 2008, p. 2). (Fernández Garcia & García Abreu, 2008, p. 2).

And it continues: Subsequently, questions may arise such as: How many experts are needed since the number to be selected could be infinite, but would it help to have such a large number of experts, and even more, what criteria should be used to select them? (Fernández Garcia & García Abreu, 2008, p. 2).

There are different methods for the selection of experts that help to define the experts professionally and are supported by proven formulations and that are used in different investigations. However, this author considers that the development of this activity before any research lacks adequate knowledge by those who apply these techniques, which negatively influences the process of expert selection. One of the problems in selecting experts is determining how competent the chosen person will be in using instruments.

For this reason, this article presents an exposition of the main methods used in different investigations. As stated at the beginning of this work, we want to propose a more expeditious and understandable methodology forresearch development.

Selection of the number of experts to be used

Regarding the number of final experts to be used in an evaluative study, it should be noted that there is no unanimous agreement on how to determine this number. However, it is estimated that the optimum number of experts to be selected should be between 15 and 30. Figure 1 shows the relationship between the number of experts used and the assumed error. Generally, the error assumed is 0.5, which represents a 95 percent confidence level(Cruz Rodriguez, 2020).

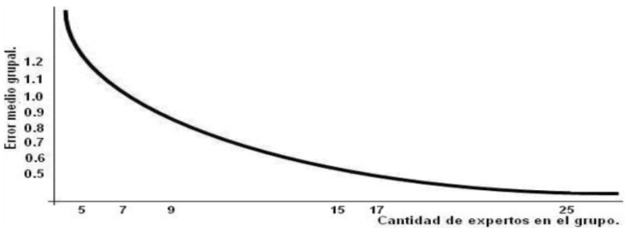


Figure 2. Relationship between the permissible error and the number of experts.
Source: Cruz Rodríguez(2020)**,** Fernandez Garcia & Garcia Abreu(2008)

The essential idea is that as the number of experts approaches 30, the error tends to zero, and the decrease in the assumed error becomes more marked from the selection of 15 experts onwards. Expressed in another way, if the researcher selects 10, 15 or 30 experts, the reliability will be 90%, 95% and 99%, respectively,concerning the criterion,it will obtain assuming that the choice of experts is adequate, the tests applied to meet the requirements of the research and the statistical processing is correct(Cruz Rodriguez, 2020)**.**

Multi-criteria method of Brajman, T. R for the selection of the number of experts.

To calculate the minimum number of experts to participate, Brajam's formula is used

$k^{(tp,n-1/\alpha)2}$ (1)

where:

K: Minimum number of experts who would participate in the survey.

β: Coefficient of variation.

α: Relative value of the confidence interval.

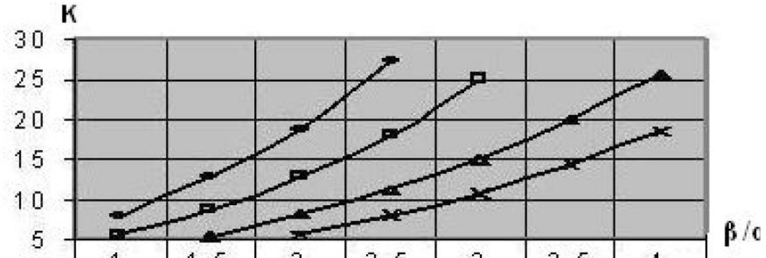
tp, n-1: Student's coefficient, tabulated in dependence on n and the confidence probability p.

n-1: Degrees of freedom.

In expression 1, non-linear concerning K, neither the coefficient of variationβnor the relative value of the confidence interval αis known. Taking into account the experience in applying the expert survey method, during the determination of the numerical composition of the group, the coefficient of variation and the relative value of the confidence interval are chosen a priori in the limitsβ= 0.2 - 0.3 and α= 0.1 - 0.2 respectively. This means that the limits of variation of the ratio

$\beta/\alpha$is between 1 and 3. (Fernández Garcia & García Abreu, 2008).

There are more explanations, but the purpose of this article is to clarify the methods of expert selection. Figure 2 shows a conceptual illustration of Brajam's method.



	1	1,5	2	2,5	3	3,5	4
p=0.95	7,8	12,9	18,7	27,4			
p=0.9	5,6	8,6	12,9	18,1	25		
p=0.8		5,4	8,2	11,2	15	20	25,8
p=0.7			5,6	8	10,8	14,4	18,6

Gráfico para la selección del número de expertos.

Figure 3. Calculation of the number of experts
Source: Fernández Garcia & García Abreu (2008).

Both methods recommend not to work with less than 15 experts since, at the time of validating instruments under certain statistics, there are calculation problems: However, when it comes to justifying the number of experts, you can cite these works where there is a clear explanation that can be defended with full knowledge of the facts.

Binomial criteria for the selection of the number of experts (N.C. 49:1981)

For the execution of this step, the procedure approved in N.C. 49:1981 Quality Control is recommended. Probabilistic criteria are used to determine the number of experts, and a binomial distribution is assumed. For this purpose, the following expression is used:

$M= P(1-P)K/i^2$

M: number of experts i: desired level of precision P: estimated proportion of experts' errors K: constant whose value is associated with the confidence level chosen. The values of K are listed in Table 1 (Rivadeneira Casanueva et al., 2021).

Table 1. Values of the constant K

Confidence level	K
99	6,6564
95	3,8416
90	6896

Source:Rivadeneira Casanueva et al.(2021).

Three ways of calculating the number of experts have been presented, and all are close to the same intervals. This means that the recommendations to use at least 15 experts prevail, but these recommendations coincide with the asymptotes in Figure 1. It should be made clear that these recommendations are based on statistical analyses that support this precision and are briefly explained in this article.

Methods

There are different methods for calculating experts, including the following:

a) DELPHI
b) Preferred methodologies
c) Pairwise comparison
d) Rignier Abacus

Expert competence coefficient "K".

Figure 3 shows the use of expert methods in a study carried out at the Faculty of Educational Studies in Holguín province.

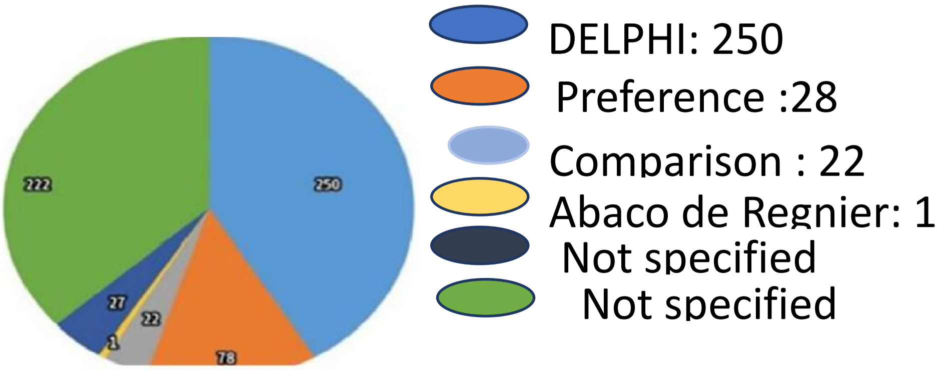


Figure 4. Use of expert methods
Source:(Cruz Rodríguez, 2020)

Description of methods

DELFHI Method

Of the most popular methods is the so-called Delphi, the authors. Mercado-Caruso et al. (2017)(2017), the Delphi is a method of structuring a group communication process that is effective in allowing a group of individuals, as a whole, to deal with a complex problem.

It was created in Santa Monica, USA at the *Research and Development Corporation* (*Rand Corporation*) to investigate the impact of technology on warfare. In this first application, carried out in 1951 and declassified 10 years later, 7 experts were asked about the future of the U.S. arsenal (Valdés & Marín, 2013).

This method uses surveys to reach a consensus on a given topic. It is a group technique where the participants do not know each other, maintaining anonymity, and having a moderator who manages the flow of information and selects the group. Figure 4 shows the flow of activities to be carried out using the Delfhi method.

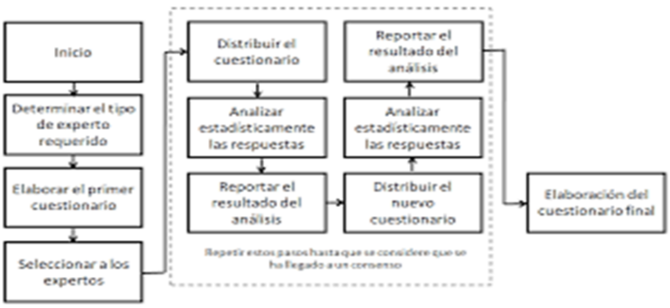


Figure 5. Flow of activities in Delfhi

Source: Da Silva(2017)

Advantages of the Delphi Method:

- It allows to obtain information from points of view on very broad or specific topics and covers a very wide variety of fields. Horizon of analysis can be varied, numerous people can participate, systematically and objectively explores problems that require concurrence and qualified opinion, eliminates or ameliorates the negative effects of "face-to-face" group meetings(Mercado-Caruso et al., 2017)

Disadvantages of the Delphi Method:

High cost, long execution time, massive participation to ensure statistical significance statistical significanceof results, high degree of correspondence of the group with the subjects treated, biases in the correct choice of participants, high number of dropouts due to time (Mercado-Caruso et al., 2017).

In a general sense, the Delphi method is feasible to apply in research where several variables are involved and scenarios are predicted for the complexity of the subject, with a duration of months of work. However, for validation works and research stages, its use is limited.

Regnier abacus

A qualitative method of consulting experts where statistical processing is reduced to a minimum to question the experts and process their answers in real time or by post on a color scale. This method does not seek consensus; its objective is to reduce uncertainty, confront points of view and become aware of the variety of opinions(Cruz Rodríguez, 2020).

Reference Method

This is the most widely used method because of its accuracy, objectivity and speed. Employing this method, the expert places the aspects evaluated according to the survey or guide prepared by the researcher in descending numerical order of quality, that is, the place occupied by each of the aspects of the guide, according to the level of quality, assigning the highest number to the highest quality and the lowest number to the lowest quality. The place is determined by the number of points accumulated: the higher the total number of points, the higher the place occupied, i.e., the higher the quality of the evaluated result(Cruz Rodríguez, 2020)

Pairwise comparison method

In this method, each expert is given a contingency table in which the aspects to be evaluated are located. Each cell of the table is related to two aspects compared, and in it is placed the number of them that, in the expert's opinion, is best reflected or manifested in the result under evaluation.

The combination of these last two methods is recurrently used in research and can be considered a competence method. The "K" Expertise Coefficient is an example of a reference and v-pairs method. The "Expert Competence" method is described below.

Expert competence coefficient "K."

This method is one of the most used and consists of an individual evaluation of the candidate (K_c) and an evaluation related to the competence (K_a). Finally, the highest result number selects the expert through a formulation (K = ½ (Kc + Ka). This method does not present a formulation for the determination of the result. Different authors are cited with this method:

(Cabero Juan & Barroso Juan, 2013)and (Romero et al. 2011).

The "Expert Competence Coefficient" calculation is based on the expert's opinion on his level of knowledge about the research problem, as well as the sources that allow him to argue the established criterion (Cabero & Barroso, 2013).

The coefficient is obtained by applying the following formula:

$K = \frac{1}{2} (Kc + Ka)$

Where:

Kc= It is the "Knowledge coefficient" or the expert's information about the subject or problem posed. It is calculated from the expert's evaluation on a scale from 0 to 10, multiplied by 0.1.

Ka= This is the so-called "Coefficient of argumentation" or substantiation of the expert's criteria. This coefficient is obtained by assigning a series of scores to the different sources of argumentation that the expert has been able to put forward. The tables show the scores usually used to assess the sources of argumentation(Cruz-Ramírez, M., & Martínez-Cepena, 2019).

This method is recurrently used in graduate work and is referred to in scientific articles. However, it should be noted that this method does not refer to calculating the number of experts involved in the research.

After a brief introduction to the methods for calculating the number of experts, the following methodology, and the calculation of experts according to their competence, the following method is proposed.

Proposal: SG Method

The proposed method used for the calculation of the number of experts of the recommendations of (Fernández Garcia & García Abreu, 2008)**,** (Cruz Rodríguez, 2020) and the selection of experts, the calculation of the Hamming's Relative Distances[1] is used, which has been used in several degree types of research in the last years. The following is its description.

Selection of the number of experts

According to the recommendations (Fernández Garcia & García Abreu, 2008), (Cruz Rodríguez, 2020), 15 experts are used, and their justification is supported in Figure 1 of, which can be proven by the binomial criterion presented in this document.

Selection of experts by competencies

For this case, fuzzy control principles can be used using the Hammming Relative Distances in their ideal condition as inference tools. (Soler Gonzalez et al., 2016) as follows

Relative Hamming Distances and Evaluation Conditions. Approximation of the optimal process

$$\delta(D_n, P_j) = \frac{1}{n}\sum_{i,j=1}^{n}|\mu_i - \mu_j| = \frac{1}{n}\left(|\mu_1 - \mu_j| + |\mu_2 - \mu_j| + \cdots + |\mu_n - \mu_j|\right) \quad (1)$$

D8 = Fuzzy subset (optimal competencies), Pj= Fuzzy subset (actual competencies) , n = Number of selected competencies,μi= Optimal competency rating,μj= Actual competency rating evaluated.

? Approximation to the ideal process

$$\eta(D_n, P_j) = \frac{1}{n}\sum_{j=1}^{n}|1 - \mu_j| \quad (2)$$

D8 = Fuzzy subset (ideal competence), Pj= Fuzzy subset (actual competences), n = Number of selected competences,μj= Actual competence rating evaluated.

Requirement of properties with different importance: Weighted Ordered Average (Canós & Liern, 2008)

$$\Pi(D_n, P_j) = \frac{1}{W}\sum_{i,j=1}^{n}V_i|\mu_i - \mu_j| = \frac{1}{W}\left(V_1|\mu_1 - \mu_j| + V_2|\mu_2 - \mu_j| + \cdots + V_n|\mu_n - \mu_j|\right) \quad (3)$$

For the case of expert selection, the ideal condition of these formulas should be used, which corresponds to the formula (2)$\eta(D_n, P_j) = \frac{1}{n}\sum_{j=1}^{n}|1 - \mu_j|$ where:

D8 = Fuzzy subset (ideal competence), Pj= Fuzzy subset (actual competences), n = Number of selected competences,μj= Actual competence rating evaluated.

For these cases, it is necessary to establish a competency evaluation grid. All organizations have performance criteria for their future and current members. Under

[1] Richard Hamming, American mathematician (1915-1988)

these characteristics, a table of competencies can be designed, the measurements can be related to different applied sciences such as statistics and fuzzy logic, to mention a few. These competencies are a function of the subject to be evaluated. The studyconsidered the evaluation criteria of the Secretariat of Higher Education and Technological Innovation of Ecuador (SENESCYT) of Ecuador that governed the evaluation of university professors during the period (2010-2017). It can also be chosen for other cases the criteria exposed in the criteria of argumentation of the method "Expert Competence Coefficient" "K" of the authors. (Cabero & Barroso, 2013). For the case of this article, a table containing the parameters and the fuzzification of the competences is created. For the selection of experts linked to higher education in Ecuador,the fuzzification process can be defined as the conversion of the set of numerical inputs into fuzzy sets(Lara-Valencia et al., 2015).

Table 2. Competencies, parameters and fuzzification.

COMPETENCY	PARAMETER	Degree of Ownership
1.-Ability to work in an interdisciplinary team.	Two projects completed	1
	A project realized	0.7
	Participation in a project	0.5
	Does not participate in projects	0.4-0.0
2.-Basic knowledge of the profession	PhD	1
	Pursuing a doctorate	0.8
	Master's degree completed	0.7
	Pursuing a master's degree	0.5
	Engineer or Bachelor's Degree	0.4-0.0
3.-Ability to evaluate knowledge in their field of study.	Doctorate in the field of study	1
	Pursuing a Ph.D. in the field of study	0.8
	Completed Master's degree in field of study	0.7
	Pursuing a master's degree in the field of study	0.5
	No studies in your field	0.4-0.0
4.-Elementary computer skills (word processing, databases, Moodle applications, etc.).	Two or more courses in computer science	1
	A course in the area of information technology	0.7
	Studying a course in computer science	0.5
	Has not taken any computer courses	0.4-0.0
5.-Knowledge of a second language	Proficiency in two languages	1
	Studying a second language	0.7
	Studying a second language	0.5
	Does not study any language	0.4-0.0
6.- Oral and written communication in their native Kichwa language.)	Certificate of National Intercultural Bilingual Management	1
	Speaking Quichua	0.7
	Speak only Spanish	0.5
7.-Research skills	Two indexed scientific articles per year	1

	One indexed scientific article per year	0.7
	One scientific article in non-indexed journals	0.5
	No items	0.4-0.0
Professional performance	Teacher evaluation 95-100%.	1
	Teacher evaluation 86% -94% -94	0.7
	Teacher evaluation 60% and-85%.	0.5
	Teacher evaluation below 60%	0.4-0.0

Source:(Soler González et al., 2016).

In this case,8 competences are fuzzified in Table 2, and 19 teachers have been chosen to choose 15 using the ideal condition formulation of Hamming's Relative Distances, which is consistent with formula 2:

$$\eta\left(D_n,P_j\right)=\frac{1}{n}\sum_{j=1}^{n}\left|1-\mu_j\right|$$

For this step, those who obtain the 15 lowest values of the relative distances will be the ones selected. Table 3 below represents the 19 participants and their ideal evaluation using the Hamming Relative Distances.

Table 3. Results of the Ideal Relative Distances of the teachers

Item	Ideal fuzzy subset	$\eta\,(D8,Pj)=1/n\sum_{i=1}^{n}\lvert 1-\mu i\rvert$ **(2) Real fuzzy subset**																		
		GT01	GT0 2	GT03	GT04	GT05	GT06	GT07	GT08	GT09	GT10	GT11	GT12	WG13	WG14	GT15	GT16	WG17	WG18	WG19
1	**1**	0,0	0,5	0,3	0,5	0,0	0,5	0,3	0,5	0,3	0,0	0,5	0,0	0,5	0,5	0,5	0,5	1,0	0,5	0,0
2	**1**	0,3	0,3	0,3	0,3	0,3	0,3	0,5	1,0	1,0	0,0	0,3	0,3	0,3	0,5	0,3	0,3	0,0	1,0	0,3
3	**1**	0,3	0,3	0,5	0,3	1,0	0,3	0,5	1,0	1,0	0,0	0,3	0,0	0,3	0,5	0,3	0,3	0,0	1,0	0,3
4	**1**	0,0	0,3	0,0	0,0	0,5	0,0	0,3	0,3	0,3	0,0	0,0	0,0	0,3	0,3	0,3	0,3	0,0	0,3	0,0
5	**1**	0,3	0,5	0,0	1,0	0,3	0,3	0,0	0,3	0,3	0,3	0,3	0,3	0,0	0,3	0,3	0,5	0,3	0,3	1,0
6	**1**	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
7	**1**	0,5	0,5	0,5	0,5	0,5	1,0	0,5	0,5	0,5	0,5	0,5	0,5	1,0	0,5	1,0	0,5	1,0	1,0	1,0
8	**1**	0,0	0,5	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,0	0,3	0,0	0,0	0,5	0,0	0,3	0,3
Relative Distance		**0,24**	**0,43**	**0,30**	**0,43**	**0,43**	**0,40**	**0,36**	**0,55**	**0,53**	**0,20**	**0,34**	**0,20**	**0,40**	**0,39**	**0,40**	**0,43**	**0,35**	**0,61**	**0,43**

Source: Soler González et al.(2016)

Table 4. Ideal results of expert selection

Experts	**IDEAL**	**Experts**	**IDEAL**
GT01	0,24	GT11	0,34
GT02	0,43	GT12	0,20
GT03	0,30	WG13	0,40
GT04	0,43	WG14	0,39

GT05	0,43	GT15	0,40
GT06	0,40	GT16	0,43
GT07	0,36	WG17	0,35
GT08	0,55	WG18	0,61
GT09	0,53	WG19	0,43
GT10	0,20		

Source:Soler González et al.(2016)

Based on these results, the 15 experts selected are as follows

Table 5. Results for the selection of experts

Experts	Experts
GT01	GT11
GT02	GT12
GT03	WG13
GT04	WG14
GT05	GT15
GT06	WG17
GT07	WG19
WG 10	

Source:(Soler González et al., 2016).

Conclusions

The article clarifies the two stages of expert selection and provides the reader with the necessary tools to justify its use. First, the proposal explains in detail the selection of the number of experts to be used, which in many investigations fall into the range of uncertainty to the detriment of the seriousness of the work. Likewise, using the criteria of confidence and the fuzzification of competences, meridian results are obtained using the demonstrable Hamming's Relative Distances.

The proposal may seem like another method and a bit cumbersome. However, it is a method that uses Hamming's formulations that are understandable and most importantly, the article provides the necessary knowledge to understand expert selection conceptually.

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