

# The Extraction of Expert Weights from Pair Wise Comparisons in Delphi Method

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## Abstract

In the second step of Delphi, it has often been seen that experts play their roles with same weights of importance. Meanwhile, some experts are clearly wiser and more powerful in such matters than others. There is no specific guidance to find the weight of importance of experts in Delphi process. Therefore, this paper intends to introduce a simple method (based on Eigenvector method - by using the number of iterations to reach convergence) to find the weight of importance of experts in Delphi process. The findings in this paper confirm the effectiveness of the proposed method. So that, inconsistent experts get less weight and vice-versa. A numerical example demonstrates the application of the proposed method.

**Keywords:** Group Decision-making, Delphi, Weights of Experts, Eigenvector

## 1. Introduction

The Delphi technique is a research approach used to gain consensus through a series of rounds of questionnaire surveys, usually two or three, where information and results are fed back to panel members between each round (Hanafin, 2004). Delphi involves a survey of people believed to be experts in the areas being studied (Zorzi and Capriati, 2001). Four key features may be regarded as necessary for defining a procedure as a 'Delphi'. These are anonymity, iteration, controlled feedback, and the statistical aggregation of group response. Anonymity is achieved through the use of questionnaires. By allowing the individual group members the opportunity to express their opinions and judgments privately, undue social

pressures – as from dominant or dogmatic individuals or from a majority – should be avoided. Ideally, this should allow the individual group members to consider each idea on the basis of merit alone, rather than on the basis of potentially invalid criteria (such as the status of an idea's proponent). Furthermore, with the iteration of the questionnaire over a number of rounds, the individuals are given the opportunity to change their opinions and judgments without fear of losing face in the eyes of the (anonymous) others in the group. Between each questionnaire iteration, controlled feedback is provided through which the group members are informed of the opinions of their anonymous colleagues. Often feedback is presented as a simple statistical summary of the group response, usually comprising a mean or median value, such as the average 'group' estimate of the date by when an event is forecast to occur. Occasionally, additional information may also be provided, such as arguments from individuals whose judgments fall outside certain pre-specified limits. In this manner, feedback comprises the opinions and judgments of all group members and not just the most vocal. At the end of the polling of participants (i.e., after several rounds of questionnaire iteration), the group judgment is taken as the statistical average (mean/median) of the panelists' estimates on the final round. The final judgment may thus be seen as an equal weighting of the members of a staticized group (Rowe and Wright, 1999).

Our paper aims to shed some light on the choice of the appropriate weight for experts based on mathematical models in Delphi process. Also, this paper intends to alleviate some Sackman critiques (discussed above), i.e. we ought to give an expert's opinion more weight than a non-perfect expert does.

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The paper is organized as follow. In section 2; Delphi, section 3; the proposed model, and Numerical example is provided in section 4. The paper is concluded in section 5.

## 2. Literature Review

Since, its design at the RAND Corporation over 40 years ago, the Delphi technique has become a widely used tool for measuring and aiding forecasting and decision making in a variety of disciplines (Rowe and Wright, 1999). The Delphi technique has been comprehensively reviewed elsewhere (e.g., (Sackman, 1974), (Powell, 2003) and (Hanafin, 2004), and so we will present a brief review only. Delphi studies were mainly applied in science, technology and education contexts (Unido Report, 2003). Blair and Uhl (Blair and Uhl, 1993), employing the Delphi technique for curriculum improvement at a Canadian university. This technique was used to identify essential course components to be included in a revised office administration program. To perform the forecasting future trends, Dick (2002), proposed to employ Delphi mail methods. Romano (2010), described the evolution of Delphi technique from its origin at the RAND Corporation in the 1950s to its use today. Identify the criteria and find the importance degree of each criterion (Hsu, 2010), (Yonghong, 2012) and (Hasanzadeh et al., 2012). Application of Delphi method joined with AHP and MCDM methods to set up comparative criteria weights (Yang and Lu, 2012) and (Pirdavani et al., 2009). Identify the differentiation between levels of expertise (Gordon, 1973). Also, in according to Gordon (1972): Brown and Helmer, used the degree of expertise via self assessment, Bender et al., used the weighting of the expert opinions; and self weighting in a Delphi studies by Catling and Rodgers. And finally, similar thoughts as this paper have been reported by Rutkowski (2008); so that Used the weighted fuzzy Delphi method to assign the weights to experts; but no presented any procedure (arbitrarily; on condition that:  $\sum W_i = 1$ ). In addition, some researchers (e.g. Dalkey and Helmer) attempted to introduce a refinement: self-rated expertise. The reasoning went something like this: an expert out to be believed more than non-experts; therefore, we ought to give an experts opinion more weight than a non-experts (Gordon, 1994). in addition, Sackman (1974) presented the considerable evidence that results based on the opinions of Laymen and experts are indistinguishable in many cases; aggregate raw opinion presented as systematic prediction; technical shortcomings, such as untested and uncontrolled halo

effects in the application of Delphi questionnaires; unsystematic and non-replica be definition and use of experts; manipulated group suggestion rather than real consensus; ambiguity in results stemming from vague questions; acceptance of snap judgments on complex issues; and the virtual absence of a vigorous critical methodological literature even though hundreds of Delphi studies have been published.

## 3. Delphi Method

The modern renaissance of futures research began with the Delphi technique at RAND, the Santa Monica, California,” think tank” in the early 1960s. The RAND researchers explored the use of expert panels to address forecasting issues. Their reasoning went something like this: experts, particularly when they agree, are more likely than nonexperts to be correct about questions in their field. However, they found that bringing experts together in a conference room introduces factors that may have little to do with the issue at hand. For example, the loudest voice rather than the soundest argument may carry the day; or, a person may be reluctant to abandon a previously stated opinion in front of this peer. As with normal thinkers, the give-and take of such face-to-face confrontations often gets in the way of a true debate (Gordon, 1994). The Delphi method is mainly used when long-term issues have to be assessed: as it is a procedure to identify statements (topics) that are relevant for the future, it reduces the tacit and complex. Knowledge to a single statement and makes it possible to judge upon (Unido Report, 2003). It has the following steps (Zorzi and Capriati, 2001):

### 1. Selection of the Subject to Forecast

It should be one where there is lack of data on future trends.

### 2. Selection of the Panel of Experts

Care is needed in recruiting the panel and the criteria for selection should be set out. Before an expert agrees to take part in a Delphi inquiry, he/she should understand the purpose of the inquiry and should be aware that his/her expertise should be made available in different rounds of the inquiry. The Delphi method has an iterative nature. If the exercise is to maintain its credibility, the tendency for panel members to drop out after the first round should be minimized.

### 3. Clarity of the Questions

Questions should be sharp and answerable. In general questions are related to the date of occurrence of an event or development, what are the possible constraints (economical, technological, social, and political) to the occurrence of event or development. Before sending the questionnaire out more widely, it should be piloted among a small sample of experts to refine it.

### 4. Administration of the Questionnaire

The questionnaire should be administrated from a person that is responsible for the management of the questionnaire and to communicate results to the panel members.

### 5. Analysis of Responses

Results are presented in a statistical manner. A common approach is as follows. For each question the median (i.e. the central tendency) and interquartile range (i.e. the middle half of the range outside which lie the upper and lower 25%, or quarters, of the range) are calculated. This information is the basis of the second round of the inquiry and it is sent to the panel members, who are asked to review their estimates in the light of the group opinion. Members who maintain an estimate outside the interquartile ranges are asked to provide a brief justification for their opinion. A new median and interquartile range can be calculated and either used as the final forecast or circulated again for further refinement. The questionnaire can circulate until convergence of opinions is reached, but a Delphi inquiry should not have more than four rounds.

### 3. Proposed Model

There are some methods for criteria weighting in decision-making process. Eigenvector method is one of these methods that use in circumstancing which decision-making matrix is not available (Eshlaghy and Farokhi, 2011). The eigenvector method was first proposed by Saaty, who proved that the principal eigenvector of the comparison matrix can be used as a required priority vector, both for consistent and inconsistent judgments of the decision maker (Srdjevic, 2005). This method is based on pair wise comparison. In pair wise comparison

method, criteria preference finds by using below table (table 1). The preference measurement scales are shown on table 2.

**Table 1: Criteria Pair Wise Comparison Matrix**

Criteria	Criterion 1	Criterion 2	Criterion j
<b>Criterion 1</b>	Criterion 1 to criterion 1	Criterion 1 to criterion 2	Criterion 1 to criterion j
<b>Criterion 2</b>	Criterion 2 to criterion 1	Criterion 2 to criterion 2	Criterion 2 to criterion j
<b>Criterion i</b>	Criterion i to criterion 1	Criterion i to criterion 2	Criterion i to criterion j

**Table 2: pair wise Comparison Scales (i to j)**

1	Equal preference
3	Poor preference
5	Strong preference
7	Very strong preference
9	Absolute preference
2,4,6,8	Intermediate preference

Matrix that introduced in table 1, always, is a square matrix and criteria that shown in rows and column will be the same. As is clear, main diameter values of the matrix will equal one, because in fact, it shows relative value and importance of each criterion to own. What happened for the rest matrix members? Let's suppose that criterion 1 has strong preference to criterion 2 then decision maker should be settling 5, in cellule 12 that is calling  $f_{12}$ . However, filling the matrix should be noticing two important following principal:

- **Reciprocal principal:** if suppose that the value preference of  $i^{th}$  criterion, to  $j^{th}$  criterion is **a** (means decision maker preference  $i^{th}$  criterion to  $j^{th}$  criterion, **a** times), logically, decision maker have to prefer  $1/a$ ,  $j^{th}$  criterion to  $i^{th}$  criterion.

$$F_{ij} = 1 / f_{ji}; i, j = 1, 2, 3 \dots n \tag{1}$$

- **Consistency principal:** decision maker should be fully remembering that if:

$$\text{Criterion 1} \leq \text{criterion 2}$$

And

$$\text{Criterion 2} \leq \text{criterion 3}$$

Then:

$$\text{Criterion 1} \leq \text{criterion 3}$$

In total consistency, have to:

$$F_{ik} f_{kj} = f_{ij}; i, j, k = 1, 2, 3 \dots n \tag{2}$$

1. In according to: Eshlaghy and Farokhi (2011, pp. 7 and 8).

In addition, the decision maker should be sure that if:

Preference of 1<sup>th</sup> criterion to 2<sup>th</sup> criterion is equal 3 and also, Preference of 2<sup>th</sup> criterion to 3<sup>th</sup> criterion is equal 2, then the preference of 1<sup>th</sup> criterion to 3<sup>th</sup> criterion have to be 2\*3=6.

The second principal, in fact, formed the basic and core concepts of this article. After establish pair wise matrix, by using following formula, the matrix must be iterated multiple times, to finally be close to convergence vector.

$$W_j = \lim_{K \rightarrow \infty} D^k \cdot e / e^t \cdot D^k \cdot e \tag{3}$$

$K \rightarrow \infty$

$K \in \text{Integer}$

That:

$W_j$  is j<sup>th</sup> weights vector

$D$  is initial pair wise comparison matrix

$e$  unit column vector that all elements are equal 1

$e^t$  is transposing matrix of  $e$ .

Number of iterations depends on the following two cases:

- If the number of criteria increases then the number of iterations of matrix for achieving to convergence vector also increases (However, this relation is not linear).
- If the decision maker inconsistency increases then the number of matrix iterations also increase.

In actual conditions, decision makers have different levels of accessible information, thinking capabilities and experience. It is impossible that in decision making process, two individual decision makers have same judgment. However, it happened by different reasons, subject to the talents and capabilities of different people, cannot achieve to the same access of resources of information and so on. Therefore, the decision maker's pair wise comparison matrixes, always, are inconsistency. It seems that if the decision makers be inconsistency in decision making process, then number of iterations to reach a convergence vector increase. So, the number of

iterations maybe a good basis, for measuring accuracy and consistency of decision makers.

When the number of iterations, for each person by using the Eigenvector method, achieved and since the sum of weights of participants in the group decision making process, should be equal to 1 (because the relative importance of decision makers should consider), then by using the following relation, weight and importance of each decision maker could be calculate:

$$\text{Absolute weight of each decision maker} = 1 - (\text{number of iterations for each decision makers} / \text{total number of iterations for all decision makers}) \tag{4}$$

And, finally by using probability scale less method:

$$\text{Relative weight of each decision maker} = \text{absolute weight of each decision maker} / \text{sum of all decision maker absolute weights (Eshlaghy and Farokhi, 2011)}. \tag{5}$$

**Notes:**

Here, two questions typically are posed:

1. In which round of Delphi, the questions should be asked and the weight should be done? The answer is; Once, before the first round.
2. Which kind of question should be asked to build up the criteria pair wise comparison matrix? The answer is; needed information can be found in their majority, work experiences and their interests in studied field.

**5. Numerical Example**

Assume that, a technology foresighted team of a new material field involves 3 expert (ex.1, ex.2, and ex.3) decides to choose the best new material. Four sub-fields have been identified<sup>2</sup>, include 1. Structure material, 2. Function material, 3. Electro-and info- material, and 4. Nano material. First, the individual preferences from the expert team are taken. The preferences are shown in table 3, 4, and 5.

2. The field and sub-fields of this example is partially taken from Qi Quan et al., (Ref. 12).

**Table 3: The ex.1 Preferences**

New material	Structure material	function material	Electro-and info- material	nano material
Structure material	1	5	5	7
function material	1/5	1	1/3	3
Electro-and info- material	1/5	3	1	9
nano material	1/7	1/3	1/9	1

**Table 4: The ex.2 Preferences**

<i>New material</i>	<i>Structure material</i>	<i>function material</i>	<i>Electro-and info- material</i>	<i>nano material</i>
Structure material	1	3	7	1/3
function material	1/3	1	1/5	9
Electro-and info- material	1/7	5	1	3
nano material	3	1/9	1/3	1

**Table 5: The ex.3 Preferences**

<i>New material</i>	<i>Structure material</i>	<i>function material</i>	<i>Electro-and info- material</i>	<i>nano material</i>
Structure material	1	7	3	9
function material	1/7	1	1	7
Electro-and info- material	1/3	1	1	1/7
nano material	1/9	1/7	7	1

The completed matrix for each expert, shown s follows:

Next, for determining the weights of the experts from the expert’s judgments (formula no. 2) eigenvector method (discussed earlier) is considered. i.e. for ex.1, we have:

$$D = \begin{vmatrix} 1 & 5 & 5 & 7 \\ 1/5 & 1 & 1/3 & 3 \\ 1/5 & 3 & 1 & 9 \\ 1/7 & 1/3 & 1/9 & 1 \end{vmatrix} = D^1; e^t = \begin{vmatrix} 1 \\ 1 \\ 1 \\ 1 \end{vmatrix}; e^t = |1 \ 1 \ 1 \ 1|$$

$$D^1.e = \begin{vmatrix} 18 \\ 4.53 \\ 13.2 \\ 1.59 \end{vmatrix}; e^t \ D^1 \ e = |1 \ 1 \ 1 \ 1| \begin{vmatrix} 18 \\ 4.53 \\ 13.2 \\ 1.59 \end{vmatrix} = 37.321$$

Then in:

First iteration:

$$W^1 = D^1.e/e^t. D^1.e = (.482 \ .121 \ .354 \ .043)$$

$$D^2 = D \ D = \begin{vmatrix} 4 & 27.33 & 12.44 & 74 \\ .895 & 4 & 2 & 10.4 \\ 2.29 & 10 & 44 & 28.4 \\ .375 & 1.71 & 1.05 & 4 \end{vmatrix}$$

$$W^2 = D^2.e/e^t. D^2.e = (.556 \ .106 \ .299 \ .039)$$

$$W^3 = D^3.e/e^t. D^3.e = (.547 \ .110 \ .302 \ .042)$$

$$W^4 = D^4.e/e^t. D^4.e = (.545 \ .110 \ .303 \ .042)$$

Finally after 5 iterations:

$$W^5 = D^5.e/e^t. D^5.e = (.545 \ .110 \ .303 \ .042)$$

As can be seen, the process has convergence in fifth iteration and the calculation got stabled. In other words,  $W^5$  is the final solution. Thus, for expert 1, number of iterations

to achieve convergence vector is equal 5. Similarly, for expert 2, number of iterations is equal 17 (first iteration: [.320 .297 .258 .125] and finally after 17 iterations: [.353 .236 .246 .166]), and for expert 3, number of iterations is equal 12 (first iteration: [.502 .229 .062 .207] and finally after 12 iterations: [.572 .213 .083 .132]).

Now according to formula no. (4) And (5) will be: No. (4)

Weight of expert 1:

$$= 1 - 5/ (5+17+12) = .85 \rightarrow .85 / (.85+.50+.65) = .425$$

Weight of expert 2:

$$= 1 - 17/ (5+17+12) = .50 \rightarrow .50 / (.85+.50+.65) = .250$$

Weight of expert 3:

$$= 1 - 12/ (5+17+12) = .65 \rightarrow .65 / (.85+.50+.65) = .325$$

As it was stated earlier, if the number of iterations in decision matrix for an expert to reach convergence is low, then expert must be having a greater weight. Therefore, expert 1 has the highest weight and expert 2 has with the lowest weight and so, these weights show the expert importance in Delphi process.

## 5. Concluding Remarks

A major drawback in second stage of Delphi (selection of the panel of experts) is that, experts play their roles with same weights of importance. Meanwhile, some experts clearly wiser and more powerful in such matters than others. In this paper, to resolve this limitation, a new approach (based on Eigenvector method - by using the

number of iteration to reach convergence) is proposed. The findings in this paper confirm the effectiveness of proposed method. So, inconsistent experts get fewer weights. To simply the process, MATLAB software could be used. In addition, in future research, similar studies can be done, for selection and composition of expert groups.

## Acknowledgment

The author wishes to thank two reviewers for his very helpful comments and suggestions.

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