Article can be accessed online at http://www.publishingindia.com

A New MADM Approach in Building Consensus in Delphi's Technique

Mohammad Azadfallah*

Abstract

There is no doubt that Delphi is a powerful technique in group decision-making context. Despite its usefulness, Delphi has some limitations too. A major drawback is the lack of transparency in reaching the consensus among the respondents. Therefore, in this paper, to resolve this limit, a new mathematical approach (based on the improved AHP models) according to Asgharpour (2003) and Azadfallah and Azizi (2015), is proposed, and can more assure the results by applying a model. A numerical example (in technologies foresight fields) demonstrates the application of the proposed method. The findings in this paper confirm the effectiveness of proposed method.

Keywords: Delphi, Consensus, AHP, Improved AHP Models

Introduction

Delphi technique is a widely used and accepted method for gathering data from respondents within their domain of expertise. The technique is designed as a group communication process which aims to achieve a convergence of opinion on a specific real-world issue (Hsu & Sandford, 2007). Linestone and Turoff provide a basic definition of the Delphi technique: "Delphi may be characterised as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem". It has application whenever policies, plans, or ideas have to be based on informed judgment. This technique is useful where the opinions and judgments of experts and practitioners are needed but time, distance, and other factors make it unlikely or impossible for the panel to work together in the same physical location. The Delphi technique, by definition, is a group process involving an interaction between the researcher and a group of identified experts on a specified topic, usually through a series of questionnaires. Delphi has been used to gain a consensus regarding future trends and projections using a systematic process of information gathering. The technique is useful where the opinions and judgments of experts and practitioners are necessary. It is especially appropriate when it is not possible to convene experts in one meeting. Skutsch and Hall identified the Delphi technique as a method for gaining judgments on complex matters where precise information is unavailable (Yousuf, 2007). In the past (Finley, 2012; from a review of 151 Delphi studies (1983-2009)) Delphi has been applied in various fields such as: Forecast, Make Decisions, Generate Ideas, Articulate Core Concepts, Set Priorities, Measure Performance, Build Capacity, and Drive Change. The set priority categories (serves to rank-order plausible alternatives) are the focus of the rest of this entry.

Multi-attribute decision making (MADM) models are selector models that are used for evaluating, ranking and selecting the most appropriate alternative from among several alternatives (Alinezhad & Amini, 2011). The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty. The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria,

* Researcher, Business Studies and Development Office, Saipa Yadak, Islamic Republic of Iran.
Email: m.azadfallah@yahoo.com

sub-criteria, and alternatives. The pertinent data are derived by using a set of pair wise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency (Gao, 2009). This study presents a new mathematical approach, based on the improved AHP models, according to Asgharpour (2003) and Azadfallah and Azizi (2015). It slightly changes the way for getting of the group pair wise comparisons. This is done by transforming the values from aij = wi / wj (in AHP) to aij = kij / kji (the improved model) which will be discussed later.

The Delphi method was designed to encourage a true debate (Gordon, 1994). 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 & Wright, 1999). The Delphi technique has been comprehensively reviewed elsewhere (e.g., Sackman, 1974; Hanafin, 2004; Stitt- gohdes & Crews, 2004; Yousuf, 2007; Plessis & Human, 2007) and so we will present a brief review only. Fink (1991) surveyed the characteristics of several major methods (Delphi, Nominal Group, and models developed by the National Institutes of Health and Glaser) and provided guidelines for those who want to use the techniques. Powell (2003) reviewed the key concepts and principles of the Delphi technique. 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. Bowles (1999) reviewed the Delphi technique and its use in nursing, medical and allied health literature between 1981 and 1998. Application of Delphi method joined with AHP and MCDM methods to set up comparative criteria weights (Yang & Lu, 2012) and (Pirdavani, 2010). In addition, there have been some reported research efforts focusing on consensus in Delphi, such as Rayens and Hahn (2000) described the use of the policy Delphi method in building consensus for public policy and to propose a technique for measuring the degree of consensus. The application of the method is illustrated by a case example from a study of state legislator's views on tobacco policy. Streveler (2003) described the use of Delphi methodology to reach consensus among a group of experienced engineering faculty about the difficulty and importance of fundamental concepts in the thermal and transport sciences. Mcintyre (2009) found for cerebral palsy are scarce and competition for them is strong. This study aimed to identify questions for future research that were agreed to be a high priority. Valerdi (2011) discussed the notion of collective intelligence through the application of the Wideband Delphi method as a way to obtain convergence among a group of experts (the wideband Delphi method enables convergence of opinion between experts after 3 rounds). Falzarano and Zipp (2013) explained how the Delphi technique has been used as a research methodology for seeking consensus among experts in the Health science literature and to offer a model for its future use. Despite its usefulness, Delphi has some notable limitations. As it was stated earlier, a major criticism was its tendency to produce a false appearance of consensus among the respondents (Stewart, 1987). Therefore, in this paper, to resolve this limit a new mathematical approach (based on the improved AHP models) according to Asgharpour (2003) and Azadfallah and Azizi (2015), is proposed, and can provide more assurance to the results by applying a model.

The paper is organised as follows. In second section Delphi, third section proposed improvement in Delphi (consensus), fourth section the proposed model, and in fifth section numerical example are provided. The paper is concluded in sixth section.

The Delphi process

Theoretically, the Delphi process can be continuously iterated until consensus is determined to have been achieved. However, Cyphert and Gant, Brooks, Ludwig, and Custer, Scarcella, and Stewart point out those three iterations are often sufficient to collect the needed information and to reach a consensus in most cases (Hsu & Sandford, 2007):

Round 1: In the first round, the Delphi process traditionally begins with an open-ended questionnaire. The open-ended questionnaire serves as the cornerstone of soliciting specific information about a content area from the Delphi subjects. After receiving subjects' responses,

investigators need to convert the collected information into a well-structured questionnaire. This questionnaire is used as the survey instrument for the second round of data collection.

Round 2: In the second round, each Delphi participant receives a second questionnaire and is asked to review the items summarised by the investigators based on the information provided in the first round. Accordingly, Delphi panelists may be required to rate or "rank-order items to establish preliminary priorities among items. As a result of round two, areas of disagreement and agreement are identified". In some cases, Delphi panelists are asked to state the rationale concerning rating priorities among items. In this round, consensus begins forming and the actual outcomes can be presented among the participants' responses.

Round 3: In the third round, each Delphi panelist receives a questionnaire that includes the items and ratings summarised by the investigators in the previous round and is asked to revise his/her judgments or "to specify the reasons for remaining outside the consensus". This round gives Delphi panelists an opportunity to make further clarifications of both the information and their judgments of the relative importance of the items. However, compared to the previous round, only a slight increase in the degree of consensus can be expected.

Characteristics of the Delphi Technique

Dalkey has identified the following basic characteristics of the Delphi technique:

1. **Anonymity:** The use of questionnaires or other communication where expressed responses are not identified as being from specific members of the panel allows for anonymity.
2. **Controlled feedback from the interaction:** Controlled feedback allows interaction with a large reduction in discord among panel members. Interaction consists of allowing interaction among group members in several stages, with the results of the previous stage summarised and group members asked to reevaluate their answers as compared to the thinking of the group.
3. **Statistical group response:** The group opinion is defined as a statistical average of the final opinions of the individual members, with the opinion of every group member reflected in the final group response (Hsu & Sandford, 2007).

Strengths

The Delphi technique is beneficial when other methods are not adequate or appropriate for data collection. It is particularly useful when

1. The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis.
2. The individuals needed to contribute to the examination of a broad or complex problem, have no history of adequate communication, and may represent diverse backgrounds with respect to experience and expertise.
3. More individuals are needed who can effectively interact in a face-to-face exchange.
4. Time and cost make frequent group meetings infeasible.
5. The efficiency of face-to-face meetings can be increased by a supplemental group communication process.
6. Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured.
7. The heterogeneity of the participants must be preserved to assure validity of the results, i.e., avoidance of domination by quantity or by strength of personality ["bandwagon effect"] (Yousuf, 2007).

Weaknesses

Every type of research has its strengths and weaknesses. It is obvious that the inappropriate choice of the Delphi technique as a research tool will typically result in failure. Linstone and Turoff suggest the following as reasons for failure:

- Imposing monitor views and preconceptions of a problem upon the respondent group by over specifying the structure of the Delphi and not allowing for the contribution of other perspectives related to the problem.
- Assuming that the Delphi can be a surrogate for all other human communications in a given situation.

- Using poor techniques of summarising and presenting the group response and ensuring common interpretations of the evaluation scales utilised in the exercise.
- Ignoring and not exploring disagreements, so that discouraged dissenters drop out and an artificial consensus is generated.
- Underestimating the demanding nature of a Delphi and the fact that the respondents should be recognised as consultants and properly compensated for their time if the Delphi is not a part of their job function.

Another weakness may include the researcher not being able to conceptualize different ways to examine the problem being investigated. As researchers become more creative in perceiving how different individuals may view the same problem in many different ways, this becomes less of a weakness. Also, if a researcher hastily tries to complete a Delphi study, thorough time for thought may not be given to the problem and consensus may not be obtained (Stitt-Gohdes & Crews, 2004).

Proposed Improvement in Delphi

Traditionally, the Delphi technique uses a series of questions seeking controlled feedback in attempt to seek the most reliable consensus among a group of experts in a specified area. The surveyors develop the questions, which can address the survey's individual question's appropriateness to the overall survey, its clarity, and appropriateness in terms of order of presentation. Experts individually respond to the questions posed for each of the survey questions. The survey developer reviews all expert responses and then modifies the tool if a pre-determined percent agreement has not been achieved. The literature does not suggest a set percent agreement, however many studies use 80%. The revised survey is then sent out to the same experts for a second round of review for those survey questions which required modifications either to clarity or to reorder the sequence based upon negative consensus agreement. This process of review and revision is continued until a set percentage agreement is met by experts (Falzarano & Zipp, 2013). The consensus reached in a Delphi may not be a true consensus; it may be a product of specious or manipulated consensus (Yousuf, 2007; Sackman, 1974). Critics and proponents of the Delphi method are widely separated on the issue of consensus. One of the original purposes of the technique was to reduce group pressure to conform, and this is often cited as one of its advantages. At the same time, the convergence of opinion observed in many Delphi studies is often taken as an indication of the value of the method (Stewart, 1987). Therefore, the object of this presentation is to show how the introduced method (the improved AHP models; by Asgharpour (2003) and Azadfallah & Azizi (2015)) can be integrated with the Delphi method (as it was stated earlier, to the set priority categories) to reduce the above drawback.

Proposed Model

In this paper, the group decision-making model based on pair wise comparison (in direction of the improved AHP models) is proposed according to Asgharpour (2003, pp. 64-70), and Azadfallah and Azizi (2015), assuming that there are m alternatives (or attributes); with k members from an expert team. The decision makers' priorities are obtained from pair wise comparison.

If we consider k_{ij} as the number of voter, where, A_i is preferred to A_j (and inversely, for k_{ji}; so that, $k_{ij} + k_{ji} = k$). Then, group decision making matrix ($D_{m.m}$); is as follows.

$$D_{m.\,m} = \begin{array}{c|cccccc} & A_1 & A_2 & \dots\dots & A_j & \dots\dots & A_m \\ A_1 & 1 & K_{12}/K_{21} & & K_{1j}/K_{j1} & & K_{1m}/K_{m1} \\ A_2 & K_{21}/K_{12} & 1 & & & & \\ \vdots & & & \ddots & & & \\ A_{i=j} & K_{i1}/K_{1i} & & & 1 & & K_{im}/K_{mi} \\ \vdots & & & & & \ddots & \\ A_m & K_{m1}/K_{1m} & K_{m2}/K_{2m} & & & & 1 \end{array}$$

(Preference Ratio Matrix)

(1)

The element of $a_{ij} = k_{ij} / k_{ji}$ denoted the ratio of voters that support A_i over A_j, to the voters that support A_j over A_i (in other words, this ratios is called relative preference intensities).

D is a positive reciprocal matrix. Therefore, it has the reciprocal property and can be decomposed to eigen value and eigen vectors. On the other hand, in this matrix, it is not required to do the consistency test. However, $a_{ij} = 1 / a_{ji}$, but in this model we have:

$a_{il}.\ a_{lj} \neq a_{ij};\ _{j \neq 1}$; Because of $(k_{il} / k_{li} . k_{lj} / k_{jl} \neq k_{ij} / k_{ji}$ OR $a_{ij} \neq a_{il} / a_{jl})$ (2)

Perron-Frobenius says that a positive squared matrix, has a real eigen value and dominant (λ max), so that, the corresponded eigen vector is weight vector priorities and unique.

The eigen value "λ max" and its corresponding eigen vector can be obtained from:

I. Decomposing D squared matrix [1] to eigen value and eigen vector:

$$D.W = \lambda. I . W \quad (3)$$

$$(D - \lambda. I) W = 0 \quad (4)$$

$$\det | D - \lambda. I | = 0 \quad (5)$$

or **II. Approximating by using the geometric mean:**

$$g_i = (\prod^{m}_{j=1} a_{ij})^{1/m} \ ; i = 1, \ldots, m. \quad (6)$$

The current method characteristics are neutrality, anonymity, monotonicity, homogeneity, and parato optimality (Asgharpour, 2003)**.**

1. The foundation of decomposition decision matrix ($D_{m.m}$) to eigen value and eigen vector is the Dogson matrix (Asgharpour, 2003).

Numerical Example

Assume that a technology foresight of priority industries team, involves the twenty experts (ex.1, ex.2… ex.20); decide to choose the appropriate plan out of the three plans (p1, agriculture technologies; p2, information technologies; and p3, advanced manufacturing technologies) for science and technology development in next five years. First, the individual preferences from the expert team are taken. The priorities are shown in Table 1.

Table 1: The Expert Preferences

Expert	Preference	Expert	Preference
ex. 1	P1>P2>P3	ex. 2	*P1>P2>P3*
ex. 3	P3>P1>P2	ex. 4	P1>P3>P2
ex. 5	P2>P3>P1	ex. 6	P2>P3>P1
ex. 7	P3>P1>P2	ex. 8	P2>P1>P3
ex. 9	P1>P2>P3	ex. 10	P1>P2>P3
ex. 11	P3>P1>P2	ex. 12	P1>P3>P2
ex. 13	P2>P3>P1	ex. 14	P2>P3>P1
ex. 15	P3>P1>P2	ex. 16	P2>P1>P3
ex. 17	P1>P2>P3	ex. 18	P1>P2>P3
ex. 19	P3>P2>P1	ex. 20	P1>P3>P2

A summary of the first step is coming in Table 2.

Table 2: The Summary of Expert's Preferences

The number of voters	*Preferences*
6	*P1>P2>P3*
4	*P3>P1>P2*
4	*P2>P3>P1*
1	*P3>P2>P1*
3	*P1>P3>P2*
2	*P2>P1>P3*

Next, the following Preference Ratio Matrix is created.

$$D_{m.m} = \begin{array}{c|ccc} & P1 & P2 & P3 \\ P1 & 1 & 13/7 & 11/9 \\ P2 & 7/13 & 1 & 12/8 \\ P3 & 9/11 & 8/12 & 1 \end{array}$$

(Ratio Preferences Matrix)

(7)

For determining the weights of the alternatives (Plans) from the expert judgments, two following method (discussed earlier) are considered.

I. decomposition of matrix method

$$\begin{array}{c|ccc} & P1 & P2 & P3 \\ P1 & 1-\lambda & 13/7 & 11/9 \\ P2 & 7/13 & 1-\lambda & 12/8 \\ P3 & 9/11 & 8/12 & 1-\lambda \end{array} = 0$$

(8)

Results as follow [2]:

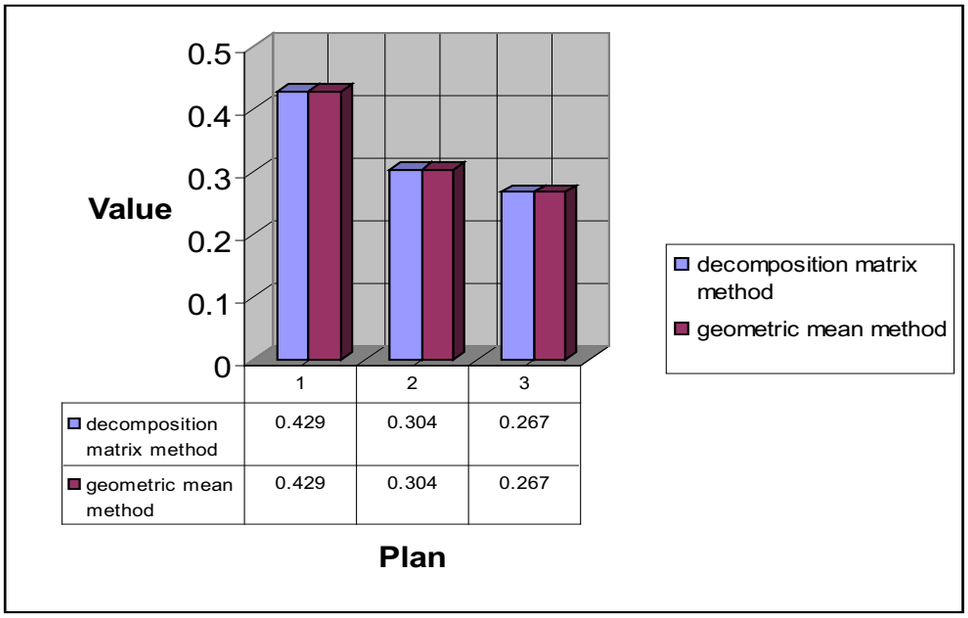
$$= 3.0759\ \lambda max \quad 1 = \lambda$$

$$2 = -0.0379 + 0.4816\ i\ \lambda \quad (9)$$

$$3 = -0.0379 - 0.4816\ i\ \lambda$$

Next, consider the following homogeneous linear equations:

AQ3: The Comparative Results



	1	2	3
decomposition matrix method	0.429	0.304	0.267
geometric mean method	0.429	0.304	0.267

$$\begin{array}{c|ccc|c|c} & P1 & P2 & P3 & & \\ P1 & -2.0759 & 13/7 & 11/9 & W1 & \\ P2 & 7/13 & -2.0759 & 12/8 & W2 & = 0 \\ P3 & 9/11 & 8/12 & -2.0759 & W3 & \end{array} \quad (10)$$

Results are as follow:

$$\rightarrow \left|\begin{matrix} W1 \\ W2 \\ W3 \end{matrix}\right| = \left|\begin{matrix} 0.429 \\ 0.304 \\ 0.267 \end{matrix}\right| \quad (11)$$

$\mathbf{W^t = \{}0.429\mathbf{,}\ 0.304\mathbf{,}\ 0.267\mathbf{\}}$

It is apparent that P1 (agriculture technologies plan) receives the highest score and thus performs better than the others. On the contrary, P3 (dvanced manufacturing technologies plan) is the worst.

2. Calculated by MATLAB software; (The supplementary reading reference: Moravej, 2009).

II. The geometric mean method

The geometric mean method is defined by:

$g_i = \{\prod^{n}_{j=1} a_{ij}\}^{1/n} \quad i = 1,2,\ldots,m.$

Results are as follow:

$$\{\prod^{3}_{j=1} a_{ij}\}^{1/3} = 1.314 \quad g_1 =$$
$$\{\prod^{3}_{j=1} a_{ij}\}^{1/3} = 0.931 \quad g_2 = \quad (12)$$
$$\{\prod^{3}_{j=1} a_{ij}\}^{1/3} = 0.817 \quad g_3 =$$

$\mathbf{W^t = \{}0.429\mathbf{,}\ 0.304\mathbf{,}\ 0.267\mathbf{\}}$

A comparison of different method results is given below.

As seen in Fig.1, the weights obtained by the geometric mean method and decomposition matrix method are the same. However, this may not happen always.

Finally, the overall weighted priorities suggest that agriculture technologies (P1) should receive maximum emphasis for science and technology development in next five years.

Conclusion

The Delphi technique is a widely used and accepted method for gathering data from respondents within their domain of expertise. A major drawback is the lack of transparency in reaching the consensus among the respondents. In this paper, to resolve this limit a new MADM approach (based on the improved AHP models) is proposed and the matrix decomposition procedure to alleviate the problem is used. The paper also compares the results with the geometric mean method and finds the same results.

References

Alinezhad, A. & Amini, A. (2011). Sensitivity analysis of Topsis technique: The results of changes in the weight of one attribute on the final ranking of alternatives. *Journal of Optimization in Industrial Engineering*, 4(7), 23-28.

Asgharpour, M. J. (2003). *Group decision making and game theory in operation research*. Tehran University Press (in Persian).

Azadfallah, M. & Azizi, M. (2015). A new approach in group decision making based on pairwise comparisons. *Journal of Business and Entrepreneurship Development*, 8(2), 159-165.

Blair, S. & Uhl, N. P. (1993). Using the Delphi method to improve the curriculum. *The Canadian Journal of Higher Education*, 23(3), 107-128.

Bowles, N. (1999). The Delphi technique. *Nursing Standard*, 13(45), 32-36.

Dick, B. (2002). *Building agreement from disagreement: The anatomy of dialectical processes.* International Congress of Action Research and Process Management. Griffith University, Grisbane, July, 1990.

Falzarano, M., & Zipp, G. P. (2013). Seeking Consensus through the use of the Delphi technique in health sciences research. *Journal of Allied Health, Summer,* 42(2), 99-105.

Finley, D. S. (2012). *Extending the Delphi method to expand its application and unlock hidden knowledge*. Symposium on Scholarship of Teaching and Learning, Mount Royal University, Banff Park Lodge, November 10, 2012.

Fink, A. (1991). *Consensus method: Characteristic and guidelines for use*. The RAND Publication Series, pp. 12.

Gao, S. (2009). *New methods of estimating weight in AHP.* Proceeding of the 2009 International Symposium on Information Processing, Huangshan, China, August 21-23, 201-204.

Gordon, T. J. (1994). *The Delphi method*. AC/UNU Millennium Project, Future Research Methodology.

anafin, S. (2004). A review of literature on the Delphi technique. Retrieved from www.childerensdatabase.ie/documents/publications/Delphi_yuechnique_A_literature_review.Pdf.

Hsu, C. C., & Sandford, B. A. (2007). Delphi Technique: Making Sense of Consensus, Practical Assessment, Research & Evaluation, 12(10). Retrieved from http://pareonline.net/getvn.asp?v=12&n=10.

Mcintyre, S. (2009). *Consensus research priorities for cerebral palsy: A Delphi survey of consumers, researchers, and clinicians*. DOI: 10.1111/j.1469-8749.2009.03358.x.

Moravej, M. T. (2009). MATLAB Key. Kelide amozesh va toseeie amozesh. (In Persian).

Pirdavani, A. (2010). *A multiple criteria decision making approach for prioritizing accident hotspots in the absence of crash data*. Retrieved from doclib.uhasselt.be/dspace/bitstream/1942/1.312/1/A1 Q2-nummer 1[1].pdf.

Plessis, E. D., & Human, S. P. (2007). The art of the Delphi technique: Highlighting its scientific merit. *Health Sa Gesondheid*, 12(4), 13-24.

Powell, C. (2003). The Delphi technique: Myths and realities. *Journal of Advanced Nursing*, 41(4), 376-382.

Rayens, M. K., & Hahn, E. J. (2000). Building consensus using the policy Delphi method. *Policy, Politics, & Nursing Practice*, 1(4), 308-315.

Romano A. (2010). Malleable Delphi: Research technique, its evaluation, and business applications. *International Review of Business Research Papers*, 6(5), 235-243.

Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: Issues and analysis. *International Journal of Forecasting*, 15(4), 353-375.

Sackman, H. (1974). *Delphi assessment: Expert opinion, forecasting, and group process*. A reported prepared for United States air force project RAND Publication.

Stewart, T. (1987). The Delphi technique and judgmental Forecasting. *Climatic Change*, 11(1), 97-113.

Stitt-Gohdes, W. L., & Crews, T. B. (2004). The Delphi technique: A research strategy for career and technical education. *Journal of Career and Technical Education*, 20(2), 55-67.

Streveler, R. A. (2003). *Using a Delphi study to identify the most difficult concepts for udents to master in thermal and transport science*. Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition.

Valerdi, R. (2011). *Convergence of expert opinion via the wideband Delphi method: An application in cost estimation models*.

Yang, L. C., & Lu, H. P. (2012). Appling Multiple Criteria Decision Making (MCDM) to evaluate the

key factors of a knowledge management system. *Information Engineering Letters*, 2(3), 28-34.

Yousuf, M. I. (2007). *Using experts' opinions through Delphi technique. practical assessment research & evaluation*, 12 (4). Retrieved from http://pareonline.net/getvn.asp?v=12&n=4.

Cyphert, F. R., & Gant, W. L. (1971). The Delphi technique: A case study. *Phi Delta Kappan,* 52, 272-273.