APIEMS BALI 2008

PROCEEDINGS

Nusa Dua
Bali - Indonesia
December 3rd - 5th, 2008

APIEMS

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REMARKS FROM CHAIRMEN
THE 9th APIEMS CONFERENCE
BALI, INDONESIA, 3 – 5 DECEMBER 2008

Welcome to the 9th Asia Pacific Industrial Engineering and Management Systems (APIEMS) Conference and to Bali, the largest tourist destination in the Indonesian archipelago. As the eight previous APIEMS conferences, this conference is organized by the Asia Pacific Industrial Engineering and Management Society (APIEMS). This society was established to achieve the following purposes: (1) to promote the dissemination of knowledge and information relating to Industrial Engineering and Management by means of meetings, publications, awarding and related activities, and (2) to promote mutual interaction and cooperation among professional organizations and staff related to the Industrial Engineering and Management discipline in the Asia Pacific Rim and in the world. Based on the purposes, this conference has set the following objectives:

- To enable the exchange of knowledge and research results about Industrial Engineering and Management
- To involve a broad range of participants from different countries, and to raise awareness of participants that the power of collaboration and interdependence can bring to producing an outcome greater than the sum of those of each individual

In addition to the above objectives, it should be noted that this conference is able to give us an experience on how to pursue our work and leisure times one after another as an integrated way of life. Both work and leisure give meaning to our lives and we need leisure time to refresh ourselves for work. In Bali, all participants could enjoy sun, beaches, watersports, cultural and artistic performances, museums, hypnotic tones of traditional music, and countless places to eat. All are certainly worth trying.

The APIEMS conference has really been an important international forum for the presentation of research results and for the exchange of the ideas on industrial engineering and management topics. The reason is that the APIEMS conferences have attracted a great number of participants from many different countries. As for this conference, it includes 361 research papers on exciting topics in Industrial Engineering and Management Systems from 22 countries, and exhibitions from our main sponsors, ILOG and Minitab. The papers will be presented in 21 tracks of 68 sessions spanning three full days. In addition to the research paper presentations, one invited keynote presentation will be given. Professor Suresh P. Sethi of School of Management, University of Texas at Dallas, USA, will speak on

an excellent topics titled “Cooperative Advertising and Pricing in a Dynamic Stochastic Supply Chain: Feedback Stackelberg Strategies.”

The fact is that so many busy people have taken the trouble to help us with their enthusiasm and professionalism in making this conference such a success. First of all, we would like to express our gratitude to the numerous referees who generously volunteered their time and expertise to review the abstracts and the full papers. Our thanks must also go to all authors who submitted excellent papers about their work to this conference. We are grateful to the APIEMS board members and the President of APIEMS for their prompt, helpful, and inspiring counsels. We are particularly indebted to the keynote speaker for his availability to come to Bali from USA and deliver his thoughtful speech. We would also like to extend our thanks to the Rector of Bandung Institute of Technology, Bandung, Indonesia, and the Rector of Sepuluh Nopember Institute of Technology, Surabaya, Indonesia, as well as to the sponsors for their supports.

Finally, we wish to acknowledge all people for their participation and contribution to the conference, and we are really looking forward to seeing all participants again at the 2009 APIEMS conference to be held in Japan.

Professor Dr. Abdul Hakim Halim
Department of Industrial Engineering
Institut Teknologi Bandung
Bandung, INDONESIA

Professor I Nyoman Pujawan, Ph.D
Department of Industrial Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, INDONESIA

GREETINGS FROM THE RECTOR OF INSTITUT TEKNOLOGI BANDUNG BANDUNG, INDONESIA

Distinguished Professors, Participants of the 2008 APIEMS Conference, Ladies and Gentlemen.

First of all I would like to extend my warmest welcome to all distinguished professors and participants at the 2008 Asia Pacific Industrial Engineering and Management Systems (APIEMS) Conference. I do hope that your stay in Bali will not only be an enjoyable experience but also provide to all of you a better opportunity to exchange research results, experience, knowledge and mutual communications among researchers and academicians. Besides, it is also an opportunity for us to make cross cultural activities among us. I am very happy to introduce that Institut Teknologi Bandung (ITB) is one of the oldest universities in Indonesia established in 1920 as Technische Hogeschool and in 1959 the university was renamed as ITB (the official English name is Bandung Institute of Technology). Since the mid of this year ITB has been celebrating its Golden Anniversary for the name of ITB by holding several academic activities, including international conferences. ITB has also allocated significant portion of its annual budget for improving education and research activities to increase its position as a World Class University.

In Indonesia, there are more than 120 universities offering higher education in Industrial Engineering, and this can be seen as a proof that Industrial Engineering (IE) is a very popular discipline in Indonesia. At ITB itself, Industrial Engineering Study Program is very popular among high school graduates and being one of the largest Study Programs that ITB has. This Study Program was established in 1971, and the number of faculty members is 45 with 880 students composing of 671 undergraduate students, 185 master students and 24 doctorate students. The graduates from this program have successfully been serving in several economic sectors such as manufacturing, transportation, banking, hospital, government and education. This means that the Industrial Engineering discipline has been making significant contributions towards the improvement of nation building, as well as to the theoretical development of Industrial Engineering methodologies. The contributions will be enriched by this three day conference that will be bringing together many of fascinating works on Industrial Engineering and Management topics from Indonesia and other countries around the world. I am sure that this conference will then be a fruitful meeting with many remarkable solutions for the current problems we are facing and for future problems that might arise.

I understand that this conference is hosted by two different Study Programs at different universities (located in different cities separated about 800 kilometers), and by BKSTI, an organization of Industrial Engineering Study Program community. What seemingly makes more complicated in managing this conference is that the venue is not in one of the cities but at a hotel separated from both universities. Accordingly, this conference has shown that the committee must have worked very hard and that with the information technology, distance is not a problem anymore. I really appreciate all the faculty members and students at both universities and the Chairman of BKSTI who have contributed so much of their time to make this conference a success.

Finally, I wish to express my gratitude to all the sponsors for their supports and to the keynote speaker and all the participants for their attendance to this conference.

Dr. Djoko Santoso
Professor and Rector
Institut Teknologi Bandung
Bandung, Indonesia

GREETINGS FROM THE RECTOR OF INSTITUT TEKNOLOGI SEPULUH NOPEMBER SURABAYA, INDONESIA

It is a great honor for me to welcome you to this conference. I am very proud that our institution has a privilege to host this prestigious conference together with Bandung Institute of Technology and the coordinating body of the Industrial Engineering education of Indonesia (BKSTI).

I learn from the conference committee that this is indeed a major conference in the field of Industrial Engineering and Management Systems in the Asia and Pacific region. This year, as I know, there will be over 340 papers presented and over 350 participants attended the conference, making this really an excellent opportunity for all of you to share research ideas, to widen your network, as well as to explore new opportunities to initiate research collaboration. I am sure everybody will take away at least one new research idea and a couple of new contacts for possible research collaboration in the future.

Our institute always encourages faculty members to be actively involved in attending or even hosting international conferences like this. It is our institute's strategic goal to be internationally recognized and we know that the most effective way of achieving this is through better visibility internationally in terms of research and publication.

I know, running a major conference has never been easy. Only those with strong commitments, courage, and patience will have an eventual success. For this reason I would like to congratulate all the committee members for having a success conference. I would also like to thank all individuals and organizations, including the keynote speaker, the reviewers, the presenters, and the sponsors for supporting this conference.

Finally, I wish you an enjoyable and productive conference.

Priyo Suprobo, Ph.D
Professor and Rector
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia

Conference Organization

Conference Chairs

Prof. Dr. Abdul Halim Hakim
Department of Industrial Engineering
Bandung Institute of Technology, Bandung - Indonesia
E-mail: ahakimhalim@lspitb.org

Prof. I Nyoman Pujawan, PhD
Department of Industrial Engineering
Sepuluh Nopember Institute of Technology, Surabaya - Indonesia
E-mail: pujawan@ie.its.ac.id

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Stochastic Judgments in the AHP:

Confidence Interval Construction Using Score Statistics

Siana Halim† [1] **and Indriati N. Bisono**[2]
Department of Industrial Engineering
Petra Christian University, Surabaya 60236, INDONESIA
Email: halim@petra.ac.id[1]
mlindri@petra.ac.id[2]

Abstract. *In multicriteria decision-making methods, such as the Analytic Hierarchy Process (AHP), single values are used to compare criteria and alternatives. Usually this single value given by decision makers follows the fundamental scale from* 1 *to* 9. *However, a decision maker often does not have complete support information for his or her making decisions. This lack of information causes the decision maker to become uncertain about his or her decisions. One of the options to overcome this problem is by using intervals instead of single-valued pairwise.*

This paper presents a methodology for analyzing the interval judgment using confidence intervals, constructed from score statistics. Moreover, inconsistency that can appear in the AHP will be restored using a consistency improving method (CIM). Data uniformly generated are used for implementing the method. The test showed that this interval judgment approach can be a representative method for covering the uncertainty in the decision-making process.

Keywords: *AHP, CIM, Score Statistics.*

1. INTRODUCTION

In classical Analytic Hierarchy Process (AHP), Saaty (1980) proposed a fundamental scale, i.e., 1-9 as a tool for helping a decision maker to make decision. The decision maker provides a single-valued pairwise preference judgments, yielding a $k \times k$ matrix $A = \{a_{ij}\}$ of preference ratios with respect to a given criterion C, where k is the number of evaluated alternatives, a_{ij} represents the relative preference of alternative i over alternative j with respect to C. A is a reciprocal matrix in which $a_{ji} = 1/a_{ij}$ for $i = 1,\ldots, k$.

However, a decision maker often does not have complete support information for his or her making decisions. This lack of information causes the decision maker to become uncertain about his or her decisions. In this case, there are several approaches to solve the problem. The two common methods are the hybrid of the AHP and Fuzzy Logic (Deng, 1999; Mikhailov, 2000, 2003; Xu, 2000) and the stochastic judgments (Stam, *et al.*, 1997; Hahn, 2003; Halim, *et al.*, 2007). The alternative solution offered in this paper is by letting the decision maker to have interval judgments about his or her preferences.

If the relative preference statements are represented by judgment intervals, rather than single values, then the rankings resulting from a classic (deterministic) AHP analysis based on single judgment values may be reversed, and therefore incorrect. Stam and Silva (1997) developed statistical techniques to obtain both point estimates and confidence intervals of the rank reversal probabilities. They also simulated the realization of a_{ij} uniformly with allowing inconsistencies between the pairwise comparisons.

In this paper we constructed confidence interval following Stam and Silva (1997). The simulation was modified to avoid inconsistencies in the pairwise comparisons using the consistency improving method (Xu, *et al.*, 1997) and setting a margin such that the improved values will be out of range (Rahardjo, *et al.*, 2001). In addition, instead of using the Clopper-Pearson statistics (1934), which was used by Stam, we proposed to use the score statistic. It is well known that the coverage probabilities of Clopper-Pearson is too high and the score statistics behaves well (Agresti, 2002).

2. METHODOLOGY

In this section we will develop the confidence interval construction as well as the consistency improving method.

†: Corresponding Author

2.1 The Confidence Interval of the Probability Rank Reversal Construction.

The construction of the confidence interval of probability of rank reversal Π_{ij} between alternatives i and j will follow Stam and Silva (1997) approached. The calculation of the rank reversal will be in the same lines as in the classical AHP methodology, therefore we need information about the true principal right eigenvector $w=(w_1,...,w_k)^T$ associated with interval judgments. Denote the pairwise comparison of alternatives i and j ($i, j = 1,\ldots, k$) by m_{ij}, and let $\boldsymbol{M} = \{m_{ij}\}$.

We simulated the realization a_{ij} for each entry of $\boldsymbol{M}$ above for $i < j$, and set $a_{ij} = 1/a_{ij}$ for $i > j$, completing the reciprocal matrix $\boldsymbol{A}$. We checked the inconsistency and modified the simulation using consistency improving method when it occurred during the simulation. For each generated $\boldsymbol{A}$, we calculated the principal right eigenvector $\boldsymbol{w}$. Replicating this simulation n times, we obtain a sample $w^1, \ldots, w^n$ principal eigenvectors.

Rank reversal between two alternatives i and j occurs when alternative i is preferred over j under perfect information (i.e. $i \succ j$), but it is calculated to be less preferred based on the sample information on the interval judgments (i.e. $w_i < w_j$). Let $\pi_{ij} = P(i \succ j)$ and $\pi_{ij}^1 = P(w_i < w_j)$, then

$$\Pi_{ij} = \pi_{ij}(1-\pi_{ij}^1) + (1-\pi_{ij})\pi_{ij}^1 \tag{1}$$

If we assume that in a given simulation trial the probability that ($W_i > W_j$) is approximately equal to the probability of ($i \succ j$) under complete information than equation (1) can be estimated as

$$\hat{\Pi}_{ij} = 2P_{ij}(1-P_{ij}) \tag{2}$$

It can be seen clearly, that (2) following the binomial distribution, $\hat{\Pi}_{ij} \sim bin(2,1)$.

The score confidence interval contains Π_0 values for which $|z_s| < z_{\alpha/2}$. Its endpoints are the Π_0 solutions to the equations

$$\frac{\hat{\Pi} - \Pi_0}{\sqrt{\Pi_0(1-\Pi_0)/n}} = \pm z_{\alpha/2} \tag{3}$$

These are quadratic in Π_0. Firstly discussed by E.B. Wilson (1927), the interval is

$$\hat{\Pi}\left(\frac{n}{n+z_{\alpha/2}}\right) + \frac{1}{2}\left(\frac{z_{\alpha/2}^2}{n+z_{\alpha/2}^2}\right) \pm z_{\alpha/2}\sqrt{\frac{1}{n+z_{\alpha/2}^2}\left[\hat{\Pi}(1-\hat{\Pi})\left(\frac{n}{n+z_{\alpha/2}^2}\right) + \left(\frac{1}{2}\right)\left(\frac{1}{2}\right)\left(\frac{z_{\alpha/2}^2}{n+z_{\alpha/2}^2}\right)\right]} \tag{4}$$

The midpoint $\tilde{\Pi}$ of the interval is a weighted average of $\hat{\Pi}$ and 1/2, where the weight $n/(n+z_{\alpha/2}^2)$ given $\hat{\Pi}$ increases as n increases.

Stam and Silva used the Cooper and Pearson *Confidence interval* (1934) as follows,

$$P_{ij}^L = \frac{p_{ij}}{p_{ij} + (1 - p_{ij} + n^{-1})F_{\alpha/2,2n(1-p_{ij}+n^{-1});2np_{ij}}}$$

$$p_{ij}^U = 1 - \frac{p_{ij}}{1 - p_{ij} + (p_{ij}+n^{-1})F_{\alpha/2,2n(p_{ij}+n^{-});2n(1-p_{ij})}} \tag{5}$$

2.2. Consistency Improving Method (CIM)

Let

$$R_k^+ = \{x = (x_1, x_2, \ldots, x_k)^r \mid x_i > 0, i = 1,2,\ldots,k\}$$

Lemma 1 *Let $\boldsymbol{A}=(a_{ij})$ is an k×k positive matrix and λ_{max} is the maximum eigenvalue of $\boldsymbol{A}$. Then*

$$\lambda_{\max} = \min_{x \in R_n^+} \max_i \sum_{j=1}^{n} a_{ij}\frac{x_j}{x_i} \tag{6}$$

Let $\boldsymbol{A}$ and λ_{max} as in Lemma 1. The *positive right eigenvector* with respect to λ_{max} is called as the *principal right eigenvector* of $\boldsymbol{A}$.

Lemma 2. *Let $x > 0$, $y > 0$, $\lambda > 0$ and $\mu > 0$, and $\lambda + \mu = 1$. Then $x^\lambda y^\mu \le \lambda x + \mu y$. The equality is reached if and only if $x = y$*

Lemma 3 *Let $\boldsymbol{A}$ is an k×k positive reciprocal matrix, λ_{max} is the maximum eigenvalue of $\boldsymbol{A}$. Then $\lambda_{max} \ge k$. The equality is reached if and only $\boldsymbol{A}$ is consistent.*

Theorem 1. *Let $\boldsymbol{A}=(a_{ij})$ is a k×k positive reciprocal matrix, and λ_{max} is the maximum eigenvalue of $\boldsymbol{A}$, $\boldsymbol{w} = (w_1, w_2, \ldots, w_n)^T$ is the principal right eigenvector of $\boldsymbol{A}$. Let*

$$\boldsymbol{B} = (b_{ij}), \text{ where } b_{ij} = (a_{ij})^\lambda \left(\frac{w_i}{w_j}\right)^{1-\lambda} \tag{7}$$

Let μ_{max} is the maximum eigenvalue of B then $\mu_{max} \le \lambda_{max}$, the equality is reached if and only if A is consistent.

Proofs of lemmas and theorem above can be seen at Xu and Wei (1999).

Through Theorem 1, the inconsistent matrices can be transformed into consistent matrices by,

$$a_{ij}^{(k+1)} = (a_{ij}^{(k)})^{\lambda} \cdot \left(\frac{w_i^{(k)}}{w_j^{(k)}} \right)^{1-\lambda} \quad (8)$$

In this transformed matrix, the consistency criteria are altered as follow

$$\delta = \max_{ij} \{ | a_{ij}^{m} - a_{ij}^{o} | \}, i, j = 1,2,...k$$

$$\sigma = \frac{\sqrt{\sum_{i=1}^{k} \sum_{j=1}^{k} \left(a_{ij}^{(n)} - a_{ij}^{(0)} \right)^2}}{k} \quad (9)$$

where $\delta < 2$ and $\sigma > 1$. CIM is valid if the consistency ratio less than 0.1.

However, Raharjo, *et al.* (2001) showed that CIM has two disadvantages. First, there is a possibility that the result of CIM lies outside the fundamental scale of AHP. Moreover, in one case study, 33.67% of resurvey results showed different result from the CIM. In the simulation these two disadvantages can be neglected. We only need to pay more attention to the first one, that is, by generated more random matrix until the consistency fulfilled and the range of each matrix elements is inside the fundamental scale.

3. NUMERICAL EXAMPLE

Suppose a decision maker decides to use AHP for comparing four alternatives $A_1,\ldots, A_4$. We simulated random uniform number between 1-9 and between 1/9-1 as the element of the comparison matrices. If these matrices are not consistent then we modified using the modified CIM until the inconsistencies in the matrices are solved. Then we normalized the matrices using geometric mean to get P_{ij}s. We used this relationship for calculating P_{ij} as follows, if A = 4B then

$$P_{ij} = \frac{A}{A+b} = \frac{4B}{4b+b} = \frac{4}{5} = 0.8$$

We constructed the confidence interval of P_{ij} using (4)

Table 1. Comparing Confidence Interval of pairwise preferences using Fisher and Score statistics

Pair (i,j)	P_{ij} Fisher	$[P_{ij}_L, P_{ij}_U]$ Fisher	Phi Scoring	$[P_{ij}_l, P_{ij}_u]$ Scoring
(1,1)	0.5	[0.0676,0.9324]	0.5	[0.1295,0.7123]
(1,2)	0.5394	[0.0833,0.9465]	0.521	[0.1833,0.7565]
(1,3)	0.5071	[0.0703,0.9351]	0.572	[0.1703,0.7351]
(1,4)	0.4855	[0.0622,0.9268]	0.518	[0.1622,0.7268]
(2,1)	0.4606	[0.0535,0.9167]	0.546	[0.1535,0.7167]
(2,2)	0.5	[0.0676,0.9324]	0.500	[0.1676,0.7324]
(2,3)	0.5463	[0.0862,0.9488]	0.573	[0.1862,0.7488]
(2,4)	0.5148	[0.0733,0.9379]	0.582	[0.1733,0.7379]
(3,1)	0.4929	[0.0649,0.9297]	0.529	[0.1649,0.797]
(3,2)	0.4537	[0.0512,0.9138]	0.535	[0.1512,0.718]
(3,3)	0.5	[0.0676,0.9324]	0.5	[0.1676,0.724]
(3,4)	0.4526	[0.0508,0.9133]	0.526	[0.1508,0.713]
(4,1)	0.5145	[0.0732,0.9378]	0.515	[0.1732,0.778]
(4,2)	0.4852	[0.0621,0.9267]	0.522	[0.1621,0.727]
(4,3)	0.5474	[0.0867,0.9492]	0.511	[0.1867,0.742]
(4,4)	0.5	[0.0676,0.9324]	0.5	[0.1676,0.732]

Table 1 shows that P_{ij} lies in between 0.5, this is true since we generated the elements of the matrices from uniform distribution. Hence, the preferences probability are equal for every alternatives. Moreover, the confidence intervals constructed via score statistics show they are narrower than ones constructed via the Pearson-Copper Statistics. Therefore, we can conclude that the score statistics are more robust than the Pearson-Copper for this case.

4. CONCLUSION

In this paper we constructed the confidence interval for preferences judgment using score statistics. We simulated the data by generated the element of the matrices uniformly and checked the consistency index using modified consistency index method. The result shows the nature of the uniformly data, that is, the equality of preferences in every alternatives.

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AUTHOR BIOGRAPHIES

Siana Halim is a lecturer at Industrial Engineering Department, Petra Christian University. She received a Dr.rer.nat from Department of Mathematics, Technische Universitaet Kaiserslautern, Germany in 2005. She has many experiences in statistical modeling for industry and was a researcher in the Department of Image Processing and Model Building Algorithm, Fraunhofer Institut fuer Techno und Wirschaft Matematik, Kaiserslautern, Germany. She is also a consultant in econometric modeling in several banks. Her teaching and research interest include credit scoring and mortgage modeling, computational statistics, nonparametric statistics, spatial statistics, Markov Random Field and applied statistics for industry. Her email address is <halim@petra.ac.id>

Indriati N. Bisono is a lecturer at Industrial Engineering Department, Petra Christian University. She received Master degree from School of Mathematical Sciences, Monash University, Australia. Her teaching and research interest include Statistical Modeling and Design of Experiment. Her email address is <mlindri@petra.ac.id>