Scientific Research and Essays Vol. 7(31), pp. 2754-2769, 9 August, 2012
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.551
ISSN 1992-2248 ©2012 Academic Journals

Full Length Research Paper

Knowledge worker productivity measurement using fuzzy analytical network process (FANP)

Asadallah Najafi

Department of Engineering, Islamic Azad University, Zanjan Branch, Moallem Avenue, Zanjan, Iran.
E-mail: asad.najafi@gmail.com. Tel: +98 214 482 6596. Fax: +98 912 294 3675.

Accepted 6 July, 2012

It is commonly recognized that knowledge is the only source of core competence in the knowledge based companies, but the productivity rate of knowledge workers is always low. Based on knowledge workers' characteristics, this paper identified factors influencing the productivity of knowledge workers and then presented improvement strategies of productivity. Finally, it selected the best strategy using fuzzy analytical network process (FANP) approach. It is hoped that this paper will help managers to implement different corresponding measures. Three case studies are presented in this paper.

Key words: Knowledge management, fuzzy analytical network process, knowledge workers productivity.

INTRODUCTION

Activities done in the fields of knowledge management are in the early stages of its growth (Bredin, 2008, (Abdel-Hamid, 1993). One of the ways that knowledge management can be successful is that it brings first make sure the organization technically have the ability to run. Human resource management is therefore important in any organization. Studies done by the researchers in 2009 identified more than 90% lead organizations implemented have adhered to this requirement, secondly factors affecting successful knowledge management should be identified. (Adkoli, 2006; Devenport, 2002).

Basic research has proven that human resources are the most important factor for improvement of knoweledge workers productivty (Afrazeh, 2001; Devenport et al., 2004; Devenport et al., 1996). Nowadays, human resources position in organization not only revised their strategic role in the successful management has been gradually accepted, but have concluded that human factors over technical issues led to successful organizations (Larson and Gobeli, 1989, Afrazeh, 2005). Despite these findings, only a small ratio of the number of empirical research has been done so far (Raiden et al., 2006, Afrazeh et al; 2003a).

In the past, organization success has been analyzed based on three main factors, including cost, time and performance (Belout et al., 2004, Afrazeh et al; 2003b). One of the fundamental problems of the past approach is lack of attention to other aspects of the knowledge workers (Hackman, 1987; Scott-Young and Samson, 2008).

The study tried to examine the most important dimensions of knowledge workers productivity improvement. Human resource management process contains the necessary coordination of human resources in the organization. Knowledge workers involved in intellectual will spend more resources (Dragan and Goran, 2001, Drucker, 1991, 1988). If management is not suitable for the organization affects output quality. The other hand, the increasing interest around knowledge worker and has caused a significant body of empirical research to emerge, examining the impact of different knowledge workers factors on knowledge worker productivity (İhsan and Metin, 2007; Kloppenborg and Opfer, 2002). However, minimum attention has been given to the conception or understanding of the specific strategies through which knowledge workers factors influence knowledge workers productivity (Afrazeh et al., 2003).

Improving productivity of knowledge workers is one of the most important challenges for companies (Drucker, 1999; Williams et al., 2004; Saaty et. al, 2003; Stylusinc, 2006; Taylor, 1998, Teece et al., 1997). Knowledge workers are obviously non-manual workers and are usually employed by organizational managers to carry out innovative activities. Knowledge worker is a member of organization who uses knowledge to be a more productive worker (Stuhlman, 2006; Ramirez, 2006; Koch and McGtath, 1996; Kriengkrai, 1998). A knowledge

Table 1. Main factors of knowledge worker productivity.

Process	Factors
Identification of knowledge	KWP_{id}
Creation of knowledge	KWP_{cr}
Capturing of knowledge	KWP_{ca}
Application of knowledge	KWP_{ap}
Sharing of knowledge	KWP_{sh}
Saving & Storage of knowledge	KWP_{ss}

worker is anyone who works for a living at the tasks of developing or using knowledge (Adkoli, 2006, Afrazeh et al; 2003a; Denis, 1989;Amar, 2002; Kuncoro, 1998; Kurttila et. al, 2000). Organizational managers that aims to continually improvement in organization, they should be consider the knowledge workers' factors as a part of the management process and as a strategic element in organizations. A scientific method is needed to classi-fication of knowledge workers' factors in organizations. it uses the fuzzy analytical network process (FANP).

This study is organized as follow. Subsequently, the study deals with knowledge workers productivity factors; then it presents research methodology and the proposed FANP algorithm; thereafter, it presents three case studies (Alupan, Mobarakeh Steel and irancell); finally, it sections analyse the research findings and present the research results and questions for future research.

Knowledge workers productivity factors

Main factors of knowledge worker productivity are achieved in six steps of knowledge management in Table 1 (Leigh, 1984; Benati, 2006; Porter, 1996; Ramírez, 2006; Ramírez and Nembhard, 2004). Knowledge worker productivity factors are introduced in Figure 1.

RESEARCH METHODOLOGY

It was decided to adopt FANP approach for this paper as there is little existing research on analysis of Knowledge workers productivity factors. It has been based on the descriptive research. This descriptive type research has been carried out using the questionnaire as the research tool for gathering the required data. Data gathering involved both reference document and a questionnaire survey. Sampling was simple random sampling and the data gathering instrument was the questionnaire.

In November 2006, a request for interviews and questionnaires was sent to a number of knowledge managers (60 persons, 40% male and 60% female, 65% over 15 years experience) and knowledge workers (60 persons, 35% male and 65% female, 65% over 20 years experience) in the Alupan company, knowledge managers (80 persons, 50% male and 50% female, 80% over 15 years experience) and knowledge workers (60 persons, 70% male and 30% female, 55% over 20 years experience) in the Mobarakeh Steel company, and knowledge managers (100 persons, 60% male and 40% female, 70% over 15 years experience) and knowledge workers (90 persons, 35% male and 65% female, 65% over 20 years experience) in the irancell company.

Prior to the interview and fill the questionnaire, the author explained the purpose of the research and made it clear that this information would be in the public domain, so any confidentiality concerns could be noted. The interview and questionnaire, from April 2007 to December 2009, lasted ten hours per week. The interview and questionnaire was semi-structured in nature, starting off with general questions on the company background and knowledge workers to put the respondent at ease.

Detailed questions based on the knowledge workers productivity factors and related frameworks were then used to gather information, with other questions included so as not to limit the information collected. Care was taken not to produce expected answers and flexibility was allowed in the process which enabled an effective two-way dialogue to emerge. To ensure internal validity, the interview and questionnaire was transcribed and sent to knowledge managers and knowledge workers in the Alupan, Mobarakeh Steel and irancell companies to check that no commercially sensitive information had been included.

Here, we present FANP method for analyzing of knowledge workers productivity factors.

The FANP method is a generalization of the Like AHP, while the AHP represents a framework with a unidirectional hierarchical AHP relationship, the FANP allows for complex interrelationships among decision levels and attributes (Dainoff, 2009). The FANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect (Yüksel and Dagˇdeviren, 2007; Lee and Kim, 2000; Lee et al, 2004).

Figure 2 presents structural difference between hierarchy (a) and network (b). FANP is considered comprehensive and explanatory for multipurpose decision-making discussions and also for solving complex decision-making issues. Studies by Yüksel and Dagˇdeviren (2007) used ANP to select information system projects that are internally dependent. These studies saw no requirement for doing an ideal zero and one programming. Karsak (2001) have used ANP in quality activity development (Mikhailov and Singh, 2003; Lee and Ahmad 2009).

A system with reflective state can be explained by a network. The structural difference between the hierarchy and the network is depicted in Figure 2. The existent element in each cluster can affect all or some of the other cluster elements. A network may contain main clusters, middle clusters, and final clusters. Arrows show the relationships in the network and their direction shows the dependence. The dependence among clusters can be named external dependence and the internal dependence among elements of a cluster can be called circle dependence (Mikhailov and Singh, 2003; Expert choice, 2000; Levitt and March, 1988; Lönnqvist, 2002). The network model used in this research is presented in Figure 3.

The proposed algorithm is derived as follows:

Step 1: Determine the element sub-factors and strategic options according to sub-factors.

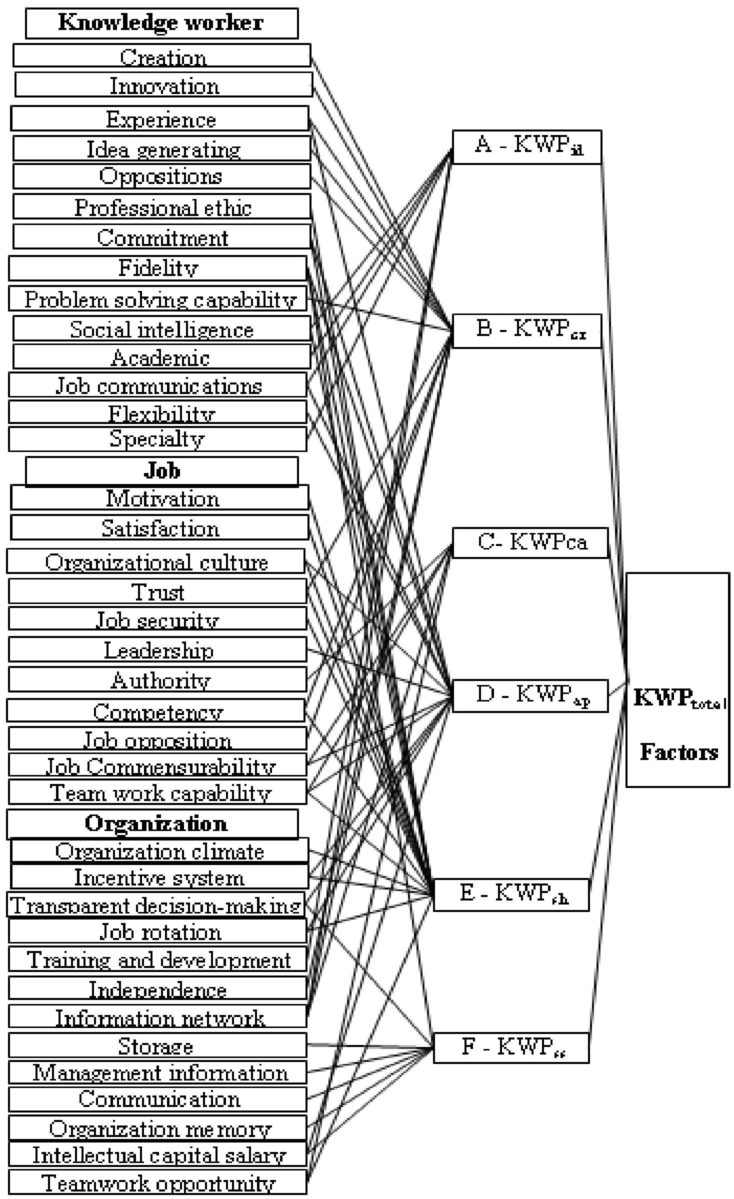

Figure 1. Knowledge worker sub factors.

Step 2: Establish the Triangular Fuzzy Numbers.
Step 3: Assume that no dependencies among element factors exist, and then the importance degree of element factors is shown by the fuzzy scale.
Step 4: Determine the element factors of the internally dependent matrix by the fuzzy scale, and consider other factors by schematic view and internal dependencies among them (W2 calculation).
Step 5: Specify the internal dependencies' priorities, that is, calculate $w_{factors} = W_2 \times w_1$.
Step 6: Specify the importance degree of element sub-factors using the fuzzy scale.
Step 7: Specify the importance degree of sub-factors.
Step 8: Specify the importance degree of strategic options, considering each sub-factor, on the fuzzy scale.
Step 9: Calculate the final priority of strategic options derived from the internal relationships among element factors and defuzzification

$$w_{alternatives} = W_4 \times w_{sub-factors(global)}.$$

CASE STUDIES

This section presents an illustration of the proposed approach summarized in the previous section. In the following case study, knowledge worker factors analysis utilizing the FANP is performed on the 3 companies.

Case 1: The Alupan is established in 1974. Its original capacity was 11 000 tonnes, and it was situated on a plot of land covering 50 000 m^2, 25 000 m of which were devoted to production. This company is one of the largest

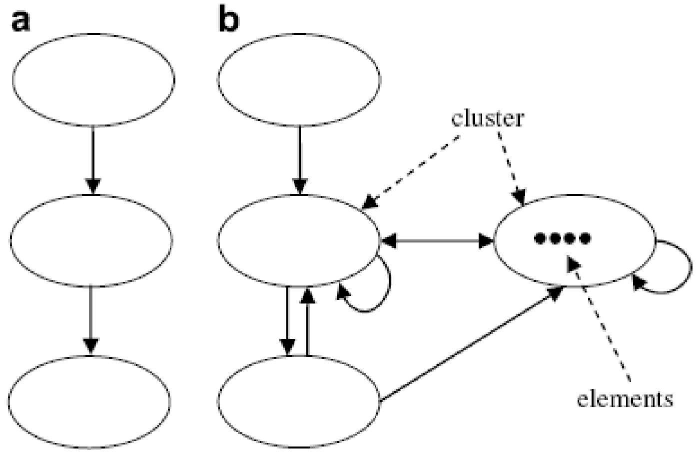

Figure 2. Structural difference between hierarchy (a) and network (b).

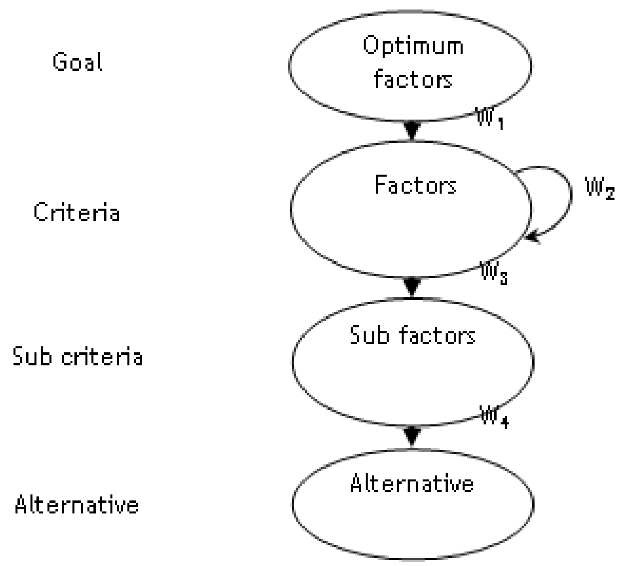

Figure 3. Network model structure.

producers in the Middle East of industrial profile sections, aluminium doors and windows and exports much of its production to Europe.

The proposed algorithm is done in Alupan Company as follows:

Step 1: First, the issue is depicted as a hierarchical structure, which contains the strategic options and sub-factors for the next calculations using FANP (Figure 4). The goal is chosen at the first level of the FANP model and the element factors (identification, creation, acquisition, application, sharing and maintenance) are determined at the second level.

The third level contains the three element sub-factors of "can", "will" and "may". Furthermore, 13 strategic options are given in the fourth level. The strategic options are as follows: (A to C) Spiritual and financial motivation based on the output work level, (A to D) Authority designation to knowledge workers and awkward rule omission, (A to E) Communicative and creative environment based on trust, (A to F) Considering knowledge workers as piece workers, not day workers, (B to D) Staff training and development, (B to E) Work cycling in organization, (B to F) Bonus and evaluation framework for organizational staff, (C to D) Creating flexible structures, (C to E) Activity transparency and intellectual property right ownership, (C to F) Creating suitable informative and communicative structures, (D to E) Creating collaboration opportunities, (D to F) Improving organizational atmosphere, (E to F) Creating job security. Knowledge worker strategies are defined in Figure 4.

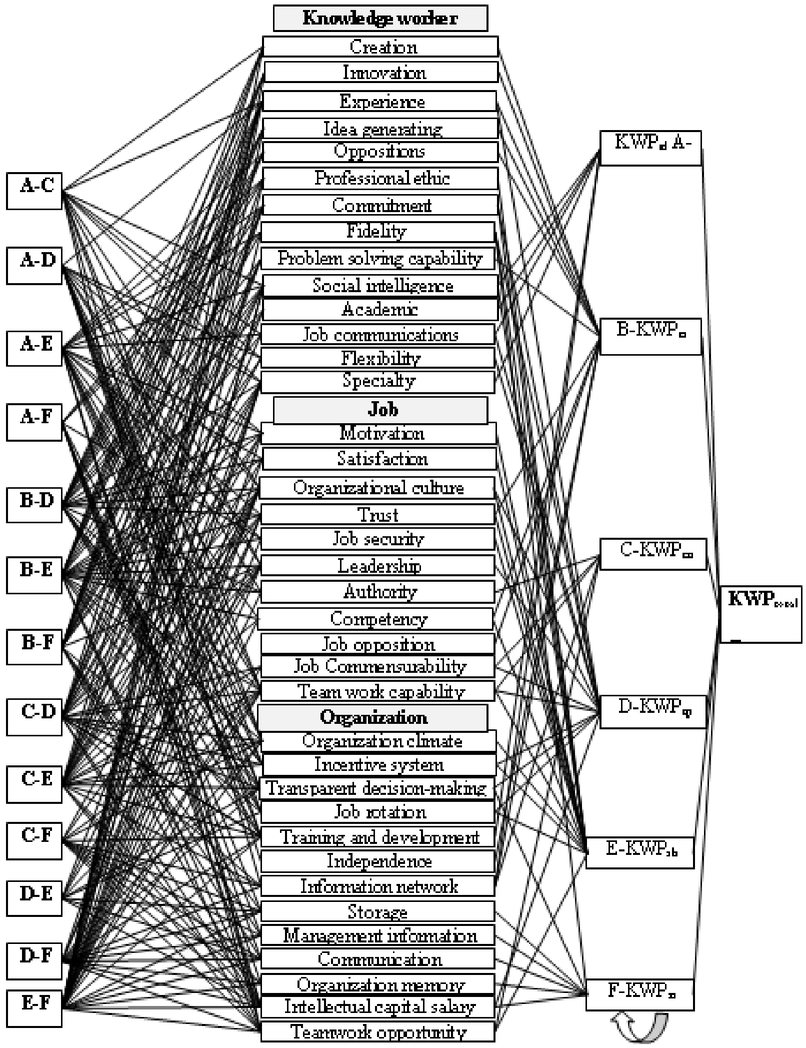

Figure 4. Strategies influencing on knowledge workers productivity.

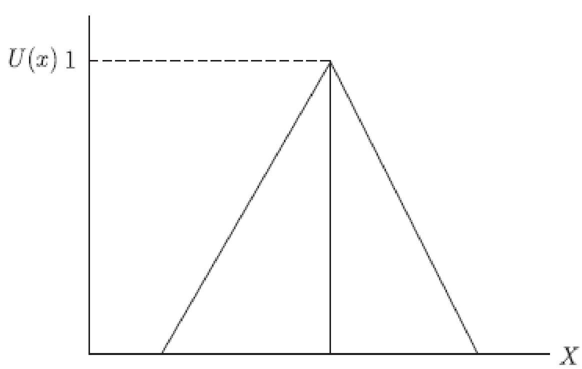

Figure 5. Triangular fuzzy numbers.

Step 2: Establish the triangular fuzzy numbers. A triangular fuzzy number (TFN) is shown in Figure 5 (Partovi and Corredoira, 2002). Since each number in the pair-wise comparison matrix represents the subjective opinion of decision makers and is an ambiguous concept, fuzzy numbers work best to consolidate fragmented expert opinions. A TFN is denoted simply as (L, M, U). The parameters L, M and U, respectively, denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event as shows in formulae (1) to (5). The triangular fuzzy numbers $\tilde{u}_{ij}$ are established as follows:

$$\tilde{u}_{ij}=(L_{ij},M_{ij},U_{ij}), \quad (1)$$

$$L_{ij} \leq M_{ij} \leq U_{ij} \text{ and } L_{ij}, M_{ij}, U_{ij}\ \varepsilon [1/9, 9], \quad (2)$$

$$L_{ij} = \min (B_{ijk}), \quad (3)$$

$$M_{ij} = \sqrt[n]{\prod B_{ijk}}, \quad (4)$$

and

$$U_{ij} = \max (B_{ijk}), \quad (5)$$

Where B_{ijk} represents a judgment of expert k for the relative importance of two criteria C_i-C_j.

Table 2. Pair wise comparisons (independent status).

Weight of factors	F	E	D	C	B	A	Factors
0.366	4	3	6	5	2	1	A
0.231	5	2	4	3	1		B
0.17	2	4	5	1			C
0.114	3	6	1				D
0.078	5	1					E
0.041	1						F

Table 3. Internal dependency matrix of factor A.

Weights	F	E	D	C	A
0.530	5	7	3	1	C
0.310	9	5	1		D
0.117	7	1			E
0.042	1				F

CR = 0.00.

Table 4. Internal dependency matrix of factor B.

Weights	F	E	D	B
0.055	1/9	1/5	1	D
0.173	1/7	1		E
0.772	1			F

CR = 0.00.

Step 3: Assume that there is no dependency among the element factors. Determine the factors' pair comparison matrix using the numerical scale of 1 to 9 (Table 2). All the pair comparisons are completed by a team of experts. The pair comparison matrix (Table 2) is analysed using expert choice software and the following special vector is obtained. In addition, a final inconsistency coefficient is shown at the end of the table.

$$W_1 = \begin{bmatrix} A \\ B \\ C \\ D \\ E \\ F \end{bmatrix} = \begin{bmatrix} .366 \\ .231 \\ .170 \\ .114 \\ .078 \\ .041 \end{bmatrix}$$

Pair wise comparisons (independent status) are defined in Table 2.

Step 4: The internal dependency among element factors is determined by comparing the effect of each factor on other factors. As mentioned in the preface, considering independence among the element factors is not always possible. Suitable and realistic results are obtained from the FANP technique and element analysis.

An analysis of internal and external environment elements reveals the element factors' dependencies as shown in Figure 5. A pair comparison matrix for factors is illustrated in Figures 4. The results obtained from the special vectors are depicted in the last column of Tables 3 to 8. The internal dependency of the element matrix, based on the calculated relative importance weights, is shown by W2. While opportunities are only influenced by strengths, a pair comparison matrix cannot be formulated for the opportunities. Internal dependency of factors is defined in Figure 6.

Internal dependency matrix of factor A is defined in Table 3. Internal dependency matrix of factor B is defined in Table 4. Internal dependency matrix of factor C is defined in Table 5. Internal dependency matrix of factor D is defined in Table 6. Internal dependency matrix of factor E is defined in Table 7. Internal dependency matrix of factor F is defined in Table 8.

$$W_2 = \begin{bmatrix} 1 & 0 & .565 & .44 & .422 & .490 \\ 0 & 1 & 0 & .307 & .329 & .249 \\ .53 & 0 & 1 & .029 & .039 & .042 \\ .31 & .055 & .056 & 1 & .078 & .081 \\ .117 & .173 & .089 & .067 & 1 & .138 \\ .042 & .772 & .290 & .157 & .131 & 1 \end{bmatrix}$$

Table 5. Internal dependency matrix of factor C.

Weights	F	E	D	A	C
0.565	5	9	3	1	A
0.056	1/9	1/5	1		D
0.089	1/7	1			E
0.290	1				F

CR = 0.00.

Table 6. Internal dependency matrix of factor D.

Weights	F	E	C	B	A	D
0.440	5	9	3	3	1	A
0.307	7	3	9	1		B
0.029	1/5	1/7	1			C
0.067	1/9	1				E
0.157	1					F

CR = 0.00.

Table 7. Internal dependency matrix of factor E.

Weights	F	D	C	B	A	E
0.422	5	7	3	3	1	A
0.329	7	5	9	1		B
0.039	1/5	1/7	1			C
0.078	1/5	1				D
0.131	1					F

CR = 0.00.

Table 8. Internal dependency matrix of factor F.

Weights	E	D	C	B	A	F
0.490	9	7	3	3	1	A
0.249	3	5	9	1		B
0.042	1/5	1/7	1			C
0.081	1/5	1				D
0.138	1					E

CR = 0.00.

$$w_{factorsw} = W_2 * W_1 = \begin{bmatrix} 1 & 0 & .565 & .44 & .422 & .490 \\ 0 & 1 & 0 & .307 & .329 & .249 \\ .53 & 0 & 1 & .029 & .039 & .042 \\ .31 & .055 & .056 & 1 & .078 & .081 \\ .117 & .173 & .089 & .067 & 1 & .138 \\ .042 & .772 & .290 & .157 & .131 & 1 \end{bmatrix} * \begin{bmatrix} .366 \\ .231 \\ .170 \\ .114 \\ .078 \\ .041 \end{bmatrix} = \begin{bmatrix} .565 \\ .302 \\ .372 \\ .260 \\ .189 \\ .312 \end{bmatrix}$$

Step 5: Priorities for internal dependencies among the factors are calculated as follows: The significant differences observed in the previous results when compared with those in Table 2 are due to the lack of information about internal dependencies. Factor priority results including A, B, C, D, E and F have changed from 0.366 to 0.565, from 0.231 to 0.302, from 0.17 to 0.372, from 0.114 to 0.260, from 0.078 to 0.189 and from 0.041 to 0.312.

Step 6: Local priorities of sub-factors are calculated using the pair comparisons matrix. The priority vector is defined in Appendixes 1, 2, 3. According the priorities, it defines vector of sub factors.

$$W_{sub-fdactors-A} = \begin{bmatrix} 0.308 \\ 0.192 \\ 0.151 \\ 0.133 \\ 0.108 \\ 0.108 \end{bmatrix}, \quad W_{sub-fdactors-B} = \begin{bmatrix} 0.352 \\ 0.181 \\ 0.150 \\ 0.110 \\ 0.150 \\ 0.062 \\ 0.031 \\ 0.028 \\ 0.022 \\ 0.015 \\ 0.009 \end{bmatrix},$$

$$W_{sub-fdactors-C} = \begin{bmatrix} 0.35 \\ 0.29 \\ 0.15 \\ 0.13 \\ 0.08 \end{bmatrix}, \quad W_{sub-fdactors-D} = \begin{bmatrix} 0.255 \\ 0.202 \\ 0.132 \\ 0.123 \\ 0.102 \\ 0.095 \\ 0.085 \\ 0.072 \\ 0.033 \\ 0.028 \\ 0.018 \\ 0.012 \\ 0.008 \end{bmatrix},$$

$$W_{sub-fdactors-E} = \begin{bmatrix} 0.208 \\ 0.119 \\ 0.113 \\ 0.122 \\ 0.106 \\ 0.095 \\ 0.084 \\ 0.052 \\ 0.034 \\ 0.025 \\ 0.018 \\ 0.012 \\ 0.008 \\ 0.003 \\ 0.001 \end{bmatrix}, \quad W_{sub-fdactors-F} = \begin{bmatrix} 0.342 \\ 0.211 \\ 0.178 \\ 0.105 \\ 0.077 \\ 0.055 \\ 0.032 \end{bmatrix}$$

Step 7: General priorities of the element sub-factors are calculated by multiplying the internal dependency priorities, obtained in Step 4, by the local priorities of element sub-factors, obtained in Step 5. The results are depicted in Appendix 1, 2, 3. Vector $W_{sub-factors(global)}$ which is obtained from the general priority amounts in the last column of Appendix 1, 2, 3 is at Appendix 4.

Step 8: The degree of strategic options' importance is calculated from each element's sub-factor viewpoints. Special vectors are calculated from the analysis of this matrix and matrix W4 in Appendix 5.

Step 9: Finally, the general priorities of strategic options are calculated considering the internal dependencies of element factors and defuzzification as follows:

$$w_{alternatives} = \begin{bmatrix} A-C \\ A-D \\ A-E \\ A-F \\ B-D \\ B-E \\ B-F \\ C-D \\ C-E \\ C-F \\ D-E \\ D-F \\ E-F \end{bmatrix} = W_4 * w_{sub-factors(global)} = \begin{bmatrix} 0.076 \\ 0.080 \\ 0.085 \\ 0.081 \\ 0.063 \\ 0.071 \\ 0.078 \\ 0.086 \\ 0.097 \\ 0.089 \\ 0.095 \\ 0.066 \\ 0.078 \end{bmatrix}$$

The general results can be organized from the highest score to the lowest. Then, according to the information in Table 9, they can be analysed.

The results of FANP analysis show that the most important strategy for knowledge worker productivity is strategy C to E or activity transparency and intellectual property right ownership whose score is 0.097. This method was tested using Cronbach's alpha (its value was more than 78.03%); it has been validated by 87% of the experts, 77% of the managers, and by company directors. The results showed a questionnaire validity of 79.7%.

Case 2: the Irancell is a private company governed by the Islamic Republic of Iran's commercial code of practice as amended in the year 1969, and the provisions of its articles of association. The company was established on the 14 August 2005. The company has been established for an indefinite period of time. The Irancell is comprised of two shareholders who are the Iran Electronic Development Company (IEDC) and MTN International (Mauritius) Limited. The company aims to become the leading power in providing telecommunication and its related to services in Iran.

Calculations of the 8 steps are done according to the Alupan case study; the general results can be organized from the highest score to the lowest. Then, according to the information in Table 10, they can be analysed.

The results of FANP analysis show that the most important strategy for knowledge worker productivity is strategy D to E or creating collaboration opportunities in organizations whose score is 0.099. This method was tested using Cronbach's alpha (its value was more than 84%); it has been validated by 78.7% of the experts, 88% of the managers, and by company directors. The result

Table 9. Final scores of strategies.

Strategies influencing on knowledge worker productivity	Score
C-E: Activity transparency and intellectual property right ownership	0.097
D-E: Creating the collaboration opportunities in organizations	0.093
C-F: Creating suitable informative and communicative structures	0.086
C-D: Creating flexible structures in organization	0.086
A-E: Communicative and creative environment based on trust	0.085
A-F: Considering the knowledge workers as piece workers, not day workers	0.081
A-D: Authority designation to knowledge workers and awkward rule omission	0.08
B-F: Bonus and evaluation framework creation for organizational staff	0.078
E-F: Creating job security in organizations	0.078
A-C: Spiritual and financial motivation creation based on the output work level	0.076
B-E: Work cycling in organization	0.061
D-F: Improving the organizational atmosphere	0.056
B-D: Staff training and development	0.043

Table 10. Final scores of strategies.

Strategies influencing on knowledge worker productivity	Score
D-E: Creating the collaboration opportunities in organizations	0.099
C-E: Activity transparency and intellectual property right ownership	0.092
A-E: Communicative and creative environment based on trust	0.088
A-F: considering the knowledge workers as piece workers, not day workers	0.086
C-F: Creating suitable informative and communicative structures	0.085
C-D: Creating flexible structures in organization	0.083
A-D: Authority designation to knowledge workers and awkward rule omission	0.081
B-E: Work cycling in organization	0.077
D-F: Improving the organizational atmosphere	0.073
B-F: Bonus and evaluation framework creation for organizational staff	0.068
E-F: Creating job security in organizations	0.06
A-C: Spiritual and financial motivation creation based on the output work level	0.055
B-D: Staff training and development	0.053

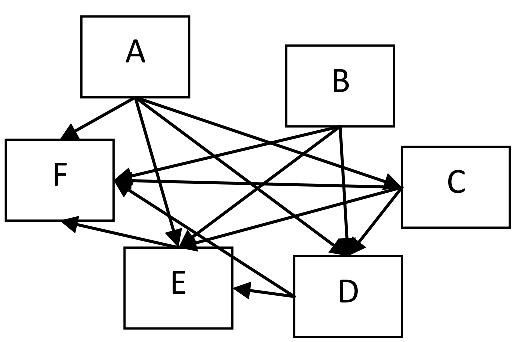

Figure 6. Internal dependency of factors.

showed a questionnaire validity of 89%.

Case 3: The Mobarakeh steel is the largest industrial complex in the Islamic Republic of Iran and has been established and commissioned after the victory of the Islamic revolution and entered into operational stage in early 1993. This company is located at 65 km from south west of Esfahan which covers a land of 35 km and has an annual capacity of 4 mt/years of flat steel products ranging in thickness from 0.18 to 16 mm in the form of hot and cold rolled coils and sheets, tinplate sheets and coils, galvanized and prepainted coils.

Calculations of the 8 steps are done according to Alupan case study; the general results can be organized from the highest score to the lowest. Then, according to the information in Table 11, they can be analysed.

The results of FANP analysis show that the most important strategy for knowledge worker productivity is strategy A to D or authority designation to knowledge workers and awkward rule omission whose score is 0.095. This method was tested using Cronbach’s alpha

Table 11. Final scores of strategies.

Strategies influencing on knowledge worker productivity	Score
A-D: Authority designation to knowledge Workers and awkward rule omission	0.095
B-F: Bonus and evaluation framework creation for organizational staff	0.094
E-F: Creating job security in organizations	0.09
A-E: Communicative and creative environment based on trust	0.089
A-F: Considering the knowledge workers as piece workers, not day workers	0.087
D-E: Creating the collaboration opportunities in organizations	0.083
C-F: Creating suitable informative and communicative structures	0.079
A-C: Spiritual and financial motivation creation based on the output work level	0.076
B-E: Work cycling in organization	0.067
D-F: Improving the organizational atmosphere	0.065
C-E: Activity transparency and intellectual property right ownership	0.063
C-D: Creating flexible structures in organization	0.06
B-D: Staff training and development	0.052

(its value was more than 88%); it has been validated by 73% of the experts, 75% of the managers, and by company directors. The results showed a questionnaire validity of 91%.

DISCUSSION

This study faced many challenges in its model validation test. The first is that the FANP model's factors are not naturally quantitative. FANP is a technique for solving multi-criteria decision making by using the dependence among quantitative and qualitative factors. However, it is not always possible to apply numerical and quantitative amounts to elements in decision making. It is also that for each calculation, different amounts resulted. This may be due to the different viewpoints among the experts who evaluated the matrix. Thus, it seems impossible to obtain similar amounts based on the data obtained from different studies. These limitations are exacerbated by the nature of decision making.

It is natural that in different circumstances, there are different priorities. It should be noted that the existent differences among the pair comparison amounts, which are due to the differences in expert view points, are not sufficient reason for rejecting the proposed model's validity in FANP discussions (Chung et al., 2005; Expert choice, 2000; Ngai, 2003). Another problem is that the validity of this model has not been tested using the latest data and that is because those data are available only to special managers.

The comparison matrix which is the input for the proposed model was composed under definite conditions; hence, results may differ due to the pair comparison matrix's composition in different time periods (Saaty, 1980). This model may be improved as the factors and sub-factors keep changing. Each management team should apply these strategies to the model according to the strategic factors in play. Second, the amount of dependence among factors and sub-factors may vary based on the management type. For example, in The Alupan, Mobarakeh Steel and irancell companies, only the dependence among important element factors is evaluated.

The inconsistent ratio resulting from the pair comparison matrix also co organizations this model. The inconsistent ratio or CR is based on the inconsistency index and random index. Inconsistency index or CI can be obtained through the following formula:

$$CI = (\lambda_{\max} - n)/(n-1)$$

where $\lambda_{\max}$ is the highest special amount and n is the matrix dimension. Inconsistency ratio (CR) is composed of two parameters (Massingham and Diment, 2009, Meredith, 2002; Momoh and Zhu, 1998): inconsistency index (CI) and random index (RI). The relationship between RI and n is as follows: RI = 1.98 * [(n – 2) / n]. Where 1.75 is the ratio of average amount of all numbers for n = 3 till n = 15, each having been multiplied by (n - 2) / n. The calculated amount for the inconsistency ratio in FANP should not be less than 0.1. The inconsistency ratio of the pair comparison matrix is calculated using expert choice.

All inconsistency ratio amounts are less than 0.1. The most important elements in knowledge workers for knowledge worker productivity are activity transparency and intellectual property right ownership. The organization's compiling the mental ownership document and implementing them is important as well. This analysis of Knowledge workers' factors for knowledge worker productivity using the proposed model is the first of its kind and is hence considered unique (Nickols, 2000; Niemira and Saaty, 2004; Paradi et. al, 2002).

Conclusion

The study has defined and classified knowledge worker productivity factors and analysed them using FANP method. Consequent to this analysis, it has presented strategies for improving of knowledge worker productivity, which were verified and validated in three case studies (Alupan, Mobarakeh Steel and irancell).

Future research

One possible follow-up is the comparison of the proposed method with other models, such as neuro-fuzzy methods.

REFERENCES

Abdel-Hamid T (1993). Adapting, correcting, and perfecting software estimates: a maintenance metaphor. Computer 26(3):20–29.

Adkoli A (2006). An agenda for ICT-enabled education, Indian Management, pp. 44-50.

Afrazeh A (2005). Knowledge management (introduction, models, measurement and implementation), Amirkabir University of Technology Pub.

Afrazeh A, Bartsch H, Hinterhuber H (2003a). Human resources productivity measurement an problem solving algorithm, Amirkabir J. Sci. Technol. 15(60-2):157-158.

Afrazeh A,Bartsch H, Hinterhuber H (2003b). Effective factors in human activities and knowledge sharing, in Zülch G (Editor), European Series in Industrial Management, Human Aspects in Production Management.6:160-167.

Afrazeh A, Najafi A, Bartsch H (2003c). Decision support system for measurement and promoting of the human resources performance. Proceedings of the 3rd International Conference on Industrial Engineering. 13-14 July, Tehran, Iran.

Amar AD (2002). Managing Knowledge workers. Unleashing Innovation and Productivty. iQuorum Books, Westport, Connecticut/London.

Belout A, Gauvreau C (2004). Factors influencing project success: the impact of human resource management, Int. J. Project Manag. 22:1-11.

Benati L (2006). Drift and breaks in labor productivity, J. Econ. Dyn. Control, Article in press.

Bredin K (2008). People capability of project-based organisations:A conceptual framework. Int. J. Project Manag. 26:566-576.

Chung SH, Lee AHL, Pearn WL (2005). Analytic network process (ANP) approach for product mix planning in semiconductor fabricator. Int. J. Prod. Econ. 96:15-36.

Dainoff MJ (2009). Can't we all just get along? Some alternative views of the Knowledge worker in complex HCI systems. Int. J. Hum. Comput. Interact. 25:328-347.

Denis fJ (1989). A methodology for the quantification of knowledge work, Phd Thesis, University of Tennessee.

Devenport T (2002). Can you boost knowledge worker's impact on the bottom line? Management Update 7(11):3-5.

Devenport T Hammer M, Leonard D (2004). Why don't we know more about knowledge?, MIT Sloan Manag. Rev. 45(4):13-19.

Devenport T, Jarvenpaa S, Beers M (1996). Improving knowledge work processes, Sloan Manag. Rev. 37(4):53-65.

Dragan K, Goran P (2001). Key acount management in an international context, Thesis work, GBS, School of Economics and Comercial Law, Goteborg Univesrity.

Drucker P (1988). The coming of the new organization, Harvard Bus. Rev. 66(1):45-53.

Drucker P (1991). The new productivity chalange, Harvard Bus. Rev. 69(6):69-80.

Drucker P (1999). Knowledge worker Productivity: The biggest chalange" California Manag. Rev. 41(2):79-94

Expert Choice (2000). Expert choice, analytical hierarchy process (AHP) Software, Version 9.5, Expert Choice, Pittsburg.

Hackman JR (1987). The design of teams. In: Lorsch, J. (Ed.), Handbook of organizational behaviour. Prenctice-Hall, Englewood Cliffs, NJ, pp. 315-342.

İhsan Y, Metin D (2007). Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile organ. Inform. Sci. 177(16):3364-3382.

Karsak EE (2001). Personnel selection using a fuzzy MCDM approach based on ideal and anti-ideal solutions, multiple criteria decision making in the new millenium, Berlin. pp. 234-276.

Kloppenborg TJ, Opfer WA (2002). The current state of project management research: trends, interpretations, and predictions. Project Manag. J. 33 (2):5-18.

Koch MJ, McGtath RG (1996). Improving labor productivity: Human resource management policies do matter" Strategic Manag. J. 17(5):335-354.

Kriengkrai T (1998). "Investigation of the effects of feedback and goal-setting on knowledge work performance in the distributed work environment" Doctor of Philisophy in indistrial and system engineering Thesis, Virginia Polytechnic Institute and State University.

Kuncoro M (1998). Strategic Thinking and CRE – A survey of recent development, University of Melbourne, Melbourne.

Kurttila M, Pesonen M, Kangas J, Kajanus M (2000). Utilizing the analytic hierarchy process (AHP) in SWOT analysis-a hybrid method and its application to a forest-certification case, Forest Policy Econ. 1:41-52.

Larson EW, Gobeli DH (1989). Significance of project management structure on development success. IEEE Trans. Eng. Manag. 36(2):119-125.

Lee JW, Kim SH (2000). Using analytic network process and goal programming for interdependent information system project selection, Comput. Oper. Res. 27:367-382.

Lee K, Lee S, Kang I (2005). KMPI: Measuring knowledge management performance. Infor. Manag. 42:469–482.

Lee HY, Ahmad KZ (2009). The moderating effects of organizational culture on the relationships between leadership behaviour and organizational commitment and between organizational commitment and job satisfaction and performance, Leadersh. Organ. Dev. J. 30(1):53-86.

Leigh JW (1984). Management in the nineties office technology and the knowledge worker, Master of science in management Thesis, Massachusetts Institute of Technology (MIT).

Levitt B, March J (1988). Organizational learning. Ann. Rev. Sociol. 14:319-40.

Lönnqvist A (2002). Measurement of intangible assets-An analysis of key concepts, Front. E-Bus. res. pp. 275-294.

Massingham P, Diment K (2009). Organizational commitment, knowledge management interventions, and learning organization capacity, Learn. Organ. 16(2):122-142.

Meredith J (2002). Developing project management theory for managerial application: the view of a research journal's editor. Paper presented at PMI Frontiers of Project Management and Research Conference. Seattle, Washington.

Mikhailov L, Singh MS (2003). Fuzzy analytic network process and its application to the development of decision support systems, IEEE Transactions on Systems, Man, and Cybernetics-Part C: Appl. Rev. 33:33-41.

Momoh JA, Zhu JZ (1998). Application of AHP/ANP to unit commitment in the deregulated power industry, IEEE Int. Conf. Syst. Man Cybern. San Diego 1:817-822.

Ngai EWT (2003). Selection of web sites for online advertising using the AHP, Inf. Manage. 40:233-242.

Nickols F (2000). What is in the world of work and working some implications of the shift to knowledge work, Butterworth-Heinemann Yearbook Knowl. Manage. Pp 1-7.

Niemira MP, Saaty TL (2004). An analytical network process model for financial-crisis forecasting, Int. J. Forecast. 20:573-587.

Paradi J, Smith SC, Schaffnit-Chatterjee C (2002). Knowledge worker performance analysis using DEA: an application to engineering design teams at Bell Canada, IEEE Trans. Eng. manag.

49(1):161-172.
Partovi FY, Corredoira RA (2002). “Quality Function Deployment for The Good of Soccer”, Eur. J. Oper. Res. 137:642-656.
Porter ME (1996). What is a strategy? Harvard Business Review (November-December) pp. 61-78.
Raide´n AB, Dainty ARJ, Neale RH (2006). Balancing employee needs, project requirements and organizational priorities in team deployment. Constr. Manag. Econ. 24:883-895.
Ramírez YW (2006). Defining measures for the intensity of knowledge work in tasks and workers, Phd Thesis in industrial Engineering. University of Wisconsin-Madison.
Ramírez YW, Nembhard DA (2004). Measuring Knowledge worker productivity: A taxonomy, J. Intellect. Cap. 5(4):602-628.
Saaty TL (1980). The Analytic Hierarchy Process, McGraw-Hill, New York, 1980.
Saaty TL, Vargas LG, Dellman K (2003). The allocation of intangible resources: the analytic hierarchy process and linear programming, Soc. Econ. Plan. Sci. (37):169-184.
Scott-Young C, Samson D (2008). Project success and project team management: Evidence from capital projects in the process industries, J. Oper. Manag. 26:749-766.
Stuhlman D (2006). Helping you turn data into knowledge : Knowledge Management Terms, Website: www.home.earthlink.net/~ddstuhlman/defin1.htm.
Stylusinc (2006). Bringing the web portal into the enterprise: Evaluate employee productivity levels and performance, Website: http://www.stylusinc.com/WebEnable/HR/EnterprisePortals.php
Taylor KS (1998). The brief reign of the knowledge worker: Information technology and technological unemployment, international conference on the social impact of information technologies in St. Louis, Missouri, U.S.A.
Teece DJ, og Pisano, G, Shuen TA (1997). Dynamic capabilities and strategic. management. Strateg. Manag. J. 18:509-533.
Williams AM, Giuse NB, Koonce TY, Kou Q, Giuse DA (2004). Using knowledge management practices to develop a state-of-the-art digital library, Stud. Health Technol. Inform. 107(Pt 1):99-103.

Appendix 1. Sub-factor priorities of A and B.

Total Priority of Sub-factor	Priority of Sub-factor	Sub-factor	Priority of factor	Factor
0.1127	0.308	Social intelligence		
0.0703	0.192	Academic level		
0.0553	0.151	Job communications	0.366	A
0.0487	0.133	Specialty		
0.0395	0.108	Training and development		
0.0395	0.108	Information network		
0.0813	0.352	Creation		
0.0418	0.181	Innovation		
0.0347	0.15	Experience		
0.0254	0.11	Idea generating		
0.0347	0.15	Oppositions		
0.0143	0.062	Problem solving capability	0.231	B
0.0072	0.031	Trust		
0.0065	0.028	Competency		
0.0051	0.022	Job opposition		
0.0035	0.015	Independence		
0.0021	0.009	Information network		

Appendix 2. Sub-factor priorities of C and D.

Total Priority of Sub-factors	Priority of Sub-factors	Sub-factors	Priority of factors	Factors
0.0595	0.35	Authority		
0.0493	0.29	Job Commensurability		
0.0255	0.15	Team work capability	0.17	**C**
0.0221	0.13	Information network		
0.0136	0.08	Teamwork opportunity		
0.0291	0.255	Experience		
0.023	0.202	Commitment		
0.015	0.132	Fidelity		
0.014	0.123	Job communications		
0.0116	0.102	Flexibility		
0.0108	0.095	Organizational culture		
0.0097	0.085	Leadership	0.114	**D**
0.0082	0.072	Job Commensurability		
0.0038	0.033	Team work capability		
0.0032	0.028	Incentive system		
0.0021	0.018	Transparent decision-making		
0.0014	0.012	Job rotation		
0.0009	0.008	Intellectual capital salary		

Appendix 3. Sub-factor priorities of E and F.

Total priority of sub-factor	Priority of sub-factor	Sub-factor	Priority of factor	Factor
0.0162	0.208	Professional ethic		
0.0093	0.119	Commitment		
0.0088	0.113	Fidelity		
0.0095	0.122	Social intelligence		
0.0083	0.106	Motivation		
0.0074	0.095	Satisfaction		
0.0066	0.084	Organizational culture		
0.0041	0.052	Trust	0.078	**E**
0.0027	0.034	Job security		
0.002	0.025	Competency		
0.0014	0.018	Team work capability		
0.0009	0.012	Organizational climate		
0.0006	0.008	Incentive system		
0.0002	0.003	Job rotation		
0.0001	0.001	Teamwork opportunity		
0.014	0.342	Fidelity		
0.0087	0.211	Transparent decision-making		
0.0073	0.178	Storage		
0.0043	0.105	Management information systems	0.041	**F**
0.0032	0.077	Communication Infrastructures		
0.0023	0.055	Organizational memory		
0.0013	0.032	Intellectual capital salary		

Appendixes 4. Vector $W_{sub-factors(global)}$.

$$W_{sub-factors} = \begin{bmatrix} 0.1127 \\ 0.0703 \\ 0.0553 \\ 0.0487 \\ 0.0395 \\ 0.0395 \\ 0.0813 \\ 0.0418 \\ 0.0347 \\ 0.0254 \\ 0.0347 \\ 0.0143 \\ 0.0072 \\ 0.0065 \\ 0.0051 \\ 0.0035 \\ 0.0021 \\ 0.0595 \\ 0.0493 \\ 0.0255 \\ 0.0221 \\ 0.0136 \\ 0.0291 \\ 0.0230 \\ 0.0150 \\ 0.0140 \\ 0.0116 \\ 0.0108 \\ 0.0097 \\ 0.0082 \\ 0.0038 \\ 0.0032 \\ 0.0021 \\ 0.0014 \\ 0.0009 \\ 0.0162 \\ 0.0093 \\ 0.0088 \\ 0.0095 \\ 0.0083 \\ 0.0074 \\ 0.0066 \\ 0.0041 \\ 0.0027 \\ 0.0020 \\ 0.0014 \\ 0.0009 \\ 0.0006 \\ 0.0002 \\ 0.0001 \\ 0.0140 \\ 0.0087 \\ 0.0073 \\ 0.0043 \\ 0.0032 \\ 0.0023 \\ 0.0013 \end{bmatrix}$$

Appendix 5. W_4 Matrix.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.05	0.03	0.10	0.01	0.06	0.10	0.11	0.04	0.08	0.10	0.09	0.03	0.05	0.06	0.08
0.11	0.10	0.07	0.05	0.09	0.09	0.01	0.12	0.14	0.06	0.07	0.03	0.06	0.14	0.12
0.09	0.06	0.10	0.08	0.13	0.12	0.01	0.12	0.08	0.11	0.11	0.01	0.04	0.12	0.06
0.08	0.05	0.10	0.11	0.06	0.12	0.03	0.05	0.13	0.05	0.07	0.13	0.15	0.13	0.05
0.04	0.05	0.07	0.01	0.13	0.04	0.04	0.06	0.01	0.04	0.08	0.16	0.01	0.03	0.07
0.08	0.05	0.06	0.11	0.07	0.07	0.09	0.01	0.07	0.09	0.07	0.01	0.08	0.01	0.00
0.11	0.01	0.10	0.03	0.04	0.11	0.08	0.06	0.08	0.16	0.03	0.05	0.05	0.05	0.16
0.06	0.13	0.04	0.15	0.02	0.04	0.14	0.06	0.02	0.04	0.06	0.09	0.12	0.08	0.01
0.09	0.16	0.08	0.10	0.11	0.12	0.12	0.08	0.06	0.01	0.10	0.18	0.12	0.00	0.02
0.06	0.14	0.08	0.10	0.04	0.00	0.12	0.08	0.05	0.14	0.09	0.16	0.15	0.14	0.15
0.12	0.11	0.10	0.11	0.10	0.09	0.16	0.16	0.05	0.04	0.08	0.04	0.09	0.10	0.10
0.01	0.11	0.04	0.05	0.02	0.01	0.08	0.13	0.15	0.04	0.04	0.01	0.08	0.10	0.06
0.12	0.01	0.08	0.09	0.13	0.11	0.01	0.03	0.09	0.14	0.10	0.10	0.00	0.05	0.12

...

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0.06	0.07	0.05	0.02	0.16	0.04	0.09	0.10	0.08	0.06	0.12	0.17	0.19	0.01	0.05
0.16	0.15	0.01	0.14	0.04	0.00	0.07	0.12	0.07	0.01	0.14	0.10	0.18	0.10	0.06
0.04	0.04	0.10	0.14	0.03	0.05	0.11	0.10	0.00	0.12	0.09	0.09	0.03	0.08	0.10
0.12	0.07	0.10	0.13	0.10	0.09	0.06	0.10	0.08	0.08	0.00	0.07	0.04	0.13	0.10
0.00	0.05	0.01	0.05	0.14	0.10	0.16	0.13	0.04	0.13	0.08	0.08	0.15	0.13	0.08
0.05	0.13	0.08	0.06	0.05	0.10	0.12	0.03	0.13	0.08	0.02	0.02	0.03	0.07	0.05
0.16	0.15	0.05	0.09	0.03	0.07	0.01	0.13	0.16	0.11	0.07	0.07	0.07	0.06	0.10
0.04	0.04	0.17	0.09	0.03	0.13	0.02	0.09	0.04	0.11	0.16	0.07	0.02	0.02	0.07
0.14	0.06	0.13	0.03	0.11	0.13	0.14	0.02	0.07	0.10	0.16	0.05	0.09	0.12	0.05
0.05	0.12	0.02	0.12	0.10	0.15	0.11	0.10	0.11	0.04	0.08	0.12	0.09	0.11	0.10
0.15	0.08	0.02	0.09	0.09	0.07	0.07	0.05	0.14	0.09	0.03	0.01	0.05	0.05	0.10
0.02	0.01	0.16	0.02	0.10	0.00	0.05	0.00	0.03	0.04	0.01	0.15	0.00	0.07	0.11
0.03	0.05	0.12	0.03	0.03	0.06	0.01	0.03	0.07	0.05	0.05	0.01	0.06	0.05	0.03

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
0.17	0.10	0.13	0.10	0.08	0.15	0.05	0.12	0.09	0.11	0.07	0.06	0.12	0.03	0.12
0.07	0.04	0.00	0.03	0.12	0.13	0.07	0.03	0.08	0.09	0.12	0.10	0.04	0.03	0.09
0.11	0.04	0.02	0.06	0.14	0.04	0.14	0.05	0.03	0.11	0.04	0.13	0.09	0.09	0.11
0.06	0.07	0.11	0.11	0.02	0.06	0.03	0.01	0.08	0.02	0.11	0.04	0.03	0.10	0.05
0.01	0.10	0.11	0.12	0.11	0.02	0.05	0.18	0.08	0.09	0.04	0.05	0.05	0.10	0.09
0.20	0.07	0.09	0.06	0.01	0.02	0.15	0.12	0.13	0.08	0.01	0.09	0.08	0.01	0.08
0.05	0.02	0.08	0.13	0.05	0.17	0.10	0.08	0.00	0.08	0.10	0.11	0.08	0.13	0.03
0.01	0.09	0.04	0.00	0.00	0.11	0.05	0.11	0.04	0.09	0.12	0.02	0.08	0.01	0.08
0.17	0.06	0.06	0.09	0.14	0.02	0.01	0.06	0.13	0.10	0.03	0.01	0.08	0.13	0.11
0.02	0.15	0.14	0.08	0.04	0.06	0.03	0.11	0.08	0.04	0.02	0.07	0.09	0.11	0.02
0.02	0.02	0.08	0.03	0.11	0.05	0.15	0.02	0.07	0.09	0.11	0.09	0.12	0.04	0.08
0.05	0.15	0.06	0.08	0.06	0.15	0.03	0.02	0.13	0.03	0.05	0.09	0.01	0.12	0.07
0.06	0.11	0.09	0.12	0.10	0.03	0.15	0.09	0.06	0.10	0.19	0.15	0.11	0.11	0.08

46	47	48	49	50	51	52	53	54	55	56	57
0.14	0.10	0.03	0.11	0.03	0.14	0.10	0.03	0.11	0.03	0.12	0.07
0.01	0.02	0.08	0.10	0.12	0.01	0.02	0.08	0.10	0.12	0.04	0.05
0.07	0.09	0.15	0.06	0.03	0.07	0.09	0.15	0.06	0.03	0.02	0.07
0.08	0.00	0.02	0.07	0.05	0.08	0.00	0.02	0.07	0.05	0.19	0.01
0.15	0.01	0.04	0.02	0.10	0.15	0.01	0.04	0.02	0.10	0.03	0.05
0.05	0.03	0.11	0.06	0.11	0.05	0.03	0.11	0.06	0.11	0.06	0.10
0.02	0.06	0.02	0.04	0.12	0.02	0.06	0.02	0.04	0.12	0.03	0.09
0.12	0.06	0.13	0.07	0.04	0.12	0.06	0.13	0.07	0.04	0.14	0.07
0.05	0.15	0.04	0.09	0.11	0.05	0.15	0.04	0.09	0.11	0.03	0.10
0.04	0.15	0.03	0.10	0.08	0.04	0.15	0.03	0.10	0.08	0.21	0.14