Ultrasound device selection by using F-ANP and COPRAS

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Ultrasound device selection by using F-ANP and COPRAS

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Abstract. Each company at a given moment must choose and decide on a required device from among the alternatives available in the market, which have distinct advantages and disadvantages to each other, such as the selection of Ultrasound as a medical device by a medical service unit. Selection can be done by using the "Fuzzy Analytic Network Process" and the "Complex Proportional Assessment" (COPRAS) method. Fuzzy ANP is used to determine the selection criteria with the highest weight, and then COPRAS is used to determine the best ultrasound sequence based on selection criteria obtained by Fuzzy ANP. The use of fuzzy ANP can give five criteria with the highest weight, and COPRAS shows the best among the five ultrasound alternatives.

1. Introduction

Manufacturing companies and service businesses generally face the problem of choosing device or equipment among several alternatives available in the market. Companies must face the problem of choosing equipment especially when procuring the equipment they need. In this case, TMC as a clinic providing health care services should use medical equipment to perform the patient's body scan to confirm the diagnosis. TMC should use ultrasound as it plays an important role in early detection of disease in the human body. [1]

Ultrasound as a radiology equipment is one of several imaging techniques used to diagnose and / or treat illness. Radiology is the key diagnostic tool for many diseases and has an important role in monitoring treatment and predicting outcome. On that basis, the management of TMC plans to make procurement of device, and must choose one between five alternatives ultrasound device available in the market. The problem in this case is, "How to choose the best ultrasound among several brands?"

To solve this problem, we try to use fuzzy-ANP and COPRAS method. The fuzzy-ANP method is used to manage inaccurate, unclear and uncertain information about decision making. The use of fuzzy provides value limits to aid in inappropriate or uncertain expert judgments in pairwise comparison processes. The fuzzy-ANP method is used because it allows discussion for a deeper relationship between criteria, where in ANP relationships at each level are not described as higher or lower, subordinate or superior, directly or indirectly [2]. The fuzzy-ANP method is also different from the AHP method with the attributes represented by the hierarchical relationship [3].

COPRAS was chosen for use rather than other alternative selection methods such as Electre, Vikor, and Topsis, because this method is simpler in its calculations. In addition, the COPRAS method also considers attributes to be maximized or minimized and uses the interval values in its assessment [4]. This method has been used effectively in CNC selection [5]. Sensitivity analysis was performed to find out the comparison of fuzzy-ANP and COPRAS method with TOPSIS and other similar methods. The sensitivity analysis shows that the fuzzy-ANP combined with COPRAS is better than other methods. The advantage of applying fuzzy-ANP with COPRAS is the assessment of the interaction between attributes in alternative evaluation with fuzzy-ANP, fewer pairwise comparisons and consistency, and no need for super matrix ratios that require complex calculations.

2. Methods

2.1. Variabel
The variables used are ultrasound device selection criteria, the scale of influence between the related criteria, the weight of each criterion, the alternative value for the criteria in the interval and the weight of each alternative.

2.2. Sampling technique
The sampling technique used for data collection in this study is judgment sampling because the questionnaire is intended for expert respondents who have knowledge of ultrasound device, namely obstetrician and ultrasound device distributor. Obstetricians are selected as respondents taking into account that the ultrasound device to be purchased will be directed for a prenatal examination based on the high pregnancy rate of patients served by TMC.

2.3. Instrument and number of respondents
The instrument used in this study is an ANP questionnaire about the relationship of influence between selection criteria, and other questionnaires that provide an alternative interval value for each criterion. The number of respondents is 4 gynecologists from RSIA hospital in Medan and 2 experts from ultrasound distributor. While the questionnaire COPRAS in the form of an alternative given to the distributor of ultrasound devices reviewed by researchers.

3. Results and Discussion

3.1. Alternative Ultrasound equipment
The number of alternatives of ultrasound device to be considered for selection are 5 devices of a similar type from different brands. Ultrasound brands are disguised using codes ie EA, EB, EC, ED and EE.

3.2. Criteria for ultrasound machine selection
Some basic criteria for ultrasound machine selection [6]

- C1: Price
- C2: Warranty / Service
  - C2-1: Allows the replacement of at least one probe/year as well as the battery.
  - C2-2: Quick service return
  - C2-3: There is 24 / 7 access to the cause of the problem by a sonographer who is familiar with the device.
  - C2-4: Components (probes and cables) must be exchangeable easily.
- C3: Durability / Maintenance
  - C3-1: Can serve multiple users and extended usage
  - C3-2: All components should be easy to clean
- C4: Size
  - C4-1: The width and length are minimum
  - C4-2: Additional drawer / storage
- C5: Reliability
  - C5-1: Fast boot-up or sleep time
  - C5-2: Battery power is durable
  - C5-3: Keyboard is not full of function keys
  - C5-4: The main buttons are marked/separated
  - C5-5: Easy to understand for beginners or users
  - C5-6: Bar code reader:
- C6: Image quality
  - C6-1: Picture quality is great for many apps
  - C6-2: High 2D image quality
  - C6-3: Has a harmonic tissue imaging, M mode, color flow and doppler pulse wave
  - C6-4: Large, high quality display that allows sightings from various angles
- C7: Probe (transducer)
  - C7-1: Strong Transducer

C7-2: Usually consists of 3 probes: cardiac (aka array of sectors or phases), linear high frequency (for vascular access, in-depth examination), bent (for the stomach)
C7-3: Multiple ports to replace probe
C7-4: A tool like a probe arm to lift a cable from the floor

C8: Image storage and archiving
C8-1: Storage, return sight and image exports should be easy
C8-2: Large hard drive capacity
C8-3: Having a PC-compatible image storage facility (JPEG, AVI or MP4)
C8-4: Has image storage facility compatible with DICOM

3.3. Analytical steps with fuzzy-ANP

3.3.1. Pairwise Comparison. Respondents were asked to perform a series of pairwise comparisons. Responses to pairwise comparisons questions were performed using a flexible fuzzy domination scale suggested by Promentilla et al. as shown in table 1. [7].

Table 1. The Fuzzy Dominance Scale for Pairwise Comparative Judgment. [7]

Numerical scale	Linguistic scaleα	Fuzzy scale(l,m,u)β
1	Just equal	(1, 1, 1)
2	Equal to moderate	(max(LB,2−d),2,min(UB, 2+d))
3	Moderate dominance	(max(LB,3−d),3,min(UB, 3+d))
4	Moderate to strong	(max(LB,4−d),4,min(UB, 4+d))
5	Strong dominance	(max(LB,5−d),5,min(UB, 5+d))
6	Strong to very strong	(max(LB,6−d),6,min(UB, 6+d))
7	Very strong dominance	(max(LB,7−d),7,min(UB, 7+d))
8	Very strong to absolute	(max(LB,8−d),8,min(UB, 8+d))
9	Absolute dominance	(max(LB,9−d),9,min(UB, 9+d))

α For pairwise verbal comparisons, dominance of element ni over element nk.
β LB and UB refers to the lower bound and upper bound of the scale, respectively.
δ indicates the degree of fuzziness.

The relationship between selection criteria is shown in table 2 and relationship model in figure 1.

Table 2. Relationship between criteria

		C1	C2				C3		C4		C5						C6				C7				C8					
		C1	C2-1	C2-2	C2-3	C2-4	C3-1	C3-2	C4-1	C4-2	C5-1	C5-2	C5-3	C5-4	C5-5	C5-6	C6-1	C6-2	C6-3	C6-4	C7-1	C7-2	C7-3	C7-4	C8-1	C8-2	C8-3	C8-4	C8-5	C8-6
C1	**C1**				V						V	V				V	V	V	V	V	V	V	V	V		V	V	V	V	V
C2	**C2-1**	V															V	V			V	V								
	C2-2	V					V																							
	C2-3	V															V	V	V				V							
	C2-4	V		V													V	V			V	V	V							
C3	**C3-1**											V																		
	C3-2																			V										
C4	**C4-1**	V						V		V			V	V						V										
	C4-2	V							V																					
C5	**C5-1**	V					V					V																		
	C5-2	V	V				V																							
	C5-3													V	V										V					
	C5-4												V		V										V					
	C5-5						V									V									V		V	V	V	
	C5-6	V					V					V																		
C6	**C6-1**	V					V					V						V												
	C6-2	V					V					V					V													
	C6-3	V					V					V	V		V		V	V									V	V		
	C6-4	V					V		V			V					V	V												
C7	**C7-1**	V	V			V	V																							
	C7-2	V																												
	C7-3	V																												
	C7-4	V						V																						
C8	**C8-1**														V												V	V		
	C8-2	V																												V
	C8-3						V																		V					
	C8-4						V																		V					
	C8-5	V					V					V													V					
	C8-6	V					V																		V	V				

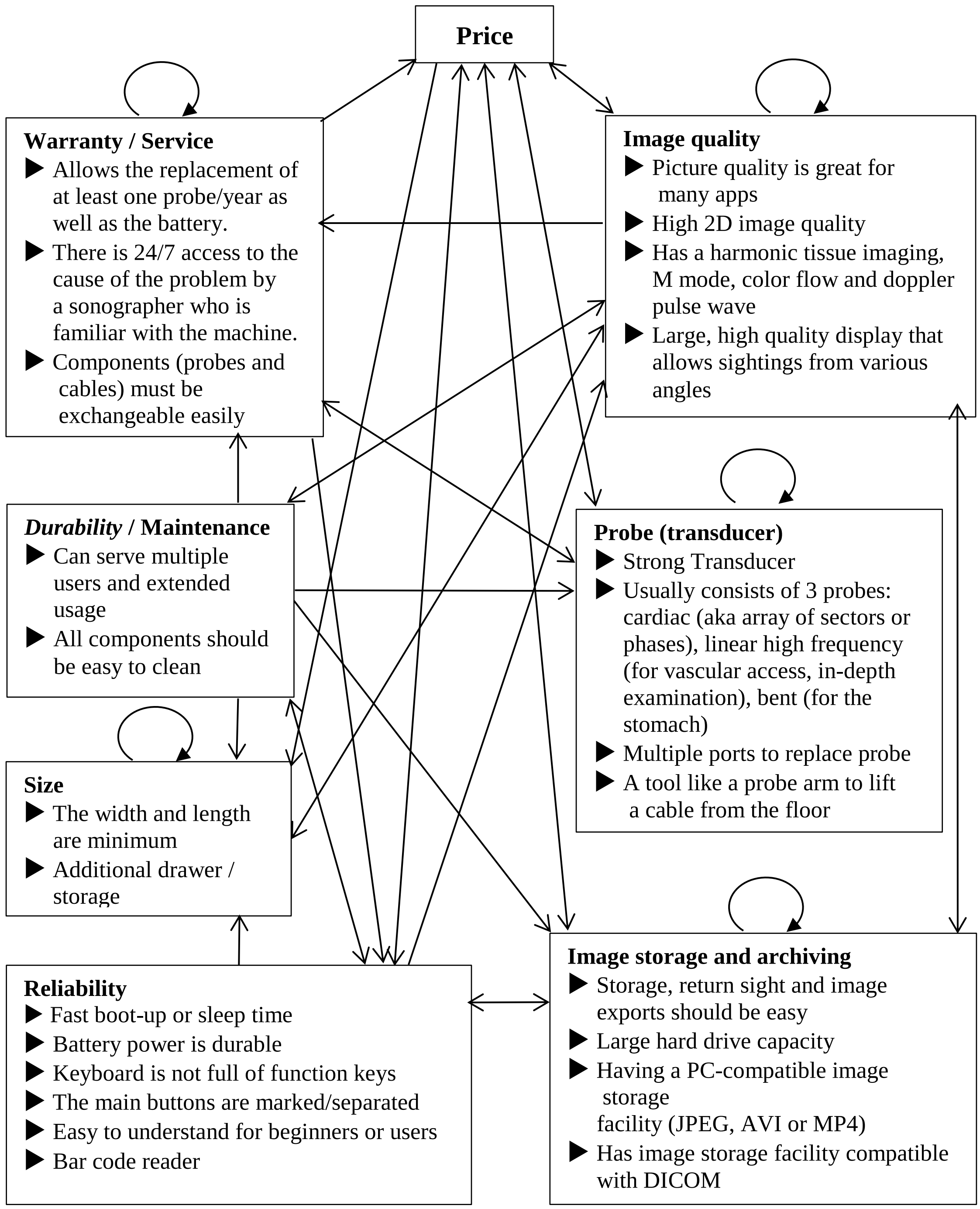

Figure 1. Network of relationships between selection criteria

3.3.2. Aggregation of Individual Judgments. Each respondent involved in the comparative judgment process provides valuable information that represents the subjective opinions and preferences, and may include some uncertainty.

3.3.3. Local Priority Estimation. After the aggregate fuzzy pairwise comparison matrices, the local priority vectors are then computed. A fuzzy version of the additive normalization method is used to approximate the fuzzy local priority. The quality of the estimation of local priorities highly depends on the consistency of judgments that the respondents (decision makers) performed throughout the pairwise comparisons.

The consistency of judgments or consistency index (CI) is calculated using the following formula.

$$CI = \frac{\lambda_{maks} - n}{n-1} \tag{1}$$

where λ_{maks} = eigen maksimum

n = the number of criteria/alternatives of the decision problem

3.3.4. Supermatrix Formation and Analysis. The unweighted supermatrix was processed by using Super Decision software, as well as the weighted matrix and the super matrix limit. The Super Decision software is used to analyze the transmission of influence along all paths defined in the network and to obtain the overall fuzzy priorities of the elements. This approach accommodates fuzziness in the supermatrix calculations and provides the opportunity to capture the uncertainty associated with the cumulative influence in form of fuzzy numbers. The method proposed in this study is based on splitting the fuzzy matrix $[G]\alpha$ into two crisp matrices denoted by L = G(α) and U =$\underline{G}$(α).

3.3.5. Defuzzification and Ranking. The total integral value method developed by Liou and Wang was employed to allow the comparison of decision elements in terms of their priorities. This method, which is independent of the type of membership functions used and the normality of the functions, can rank more than two fuzzy numbers simultaneously. It is relatively simple in computation, especially in ranking triangular fuzzy numbers. The elements with the highest normalized importance values, and thereby having the highest rankings, are selected to establish the set of the most critical (dominant) elements in the decision problem. Table 3 shows the results of the weighting criteria of fuzzy ANP.

Tabel 3. Weight of Criteria

No.	Code	Weight	No.	Code	Weight	No.	Code	Weight
1	C1	0,1119	10	C5-1	0,0067	20	C7-1	0,2633
2	C2-1	0,1334	11	C5-2	0,0196	21	C7-2	0,0069
3	C2-2	0,0066	12	C5-3	0,0080	22	C7-3	0,0040
4	C2-3	0,0178	13	C5-4	0,0061	23	C7-4	0,0103
5	C2-4	0,1367	14	C5-5	0,0066	24	C8-1	0,0028
6	C3-1	0,0037	15	C5-6	0,0065	25	C8-2	0,0147
7	C3-2	0,0128	16	C6-1	0,0120	26	C8-3	0,0004
8	C4-1	0,0774	17	C6-2	0,0102	27	C8-4	0,0004
9	C4-2	0,0639	18	C6-3	0,0147	28	C8-5	0,0087
			19	C6-4	0,0218	29	C8-6	0,0119

3.4. Complex Proportional Assessment (COPRAS)

Selection of ultrasound device is done by using COPRAS method to determine the order of each alternatip based on its weight. Determination of weights is done by using selection criteria obtained from the implementation of F-ANP.

3.4.1. Constructing the decision X matrix. The decision matrix X with 5 alternatives (N) and 29 attributes (M) is represented below.

$$X = \begin{bmatrix} x_{11}, u_{11} & x_{12}, u_{12} & \cdots & x_{1M}, u_{1M} \\ x_{21}, u_{21} & x_{22}, u_{22} & \vdots & x_{2M}, u_{2M} \\ \cdots & \cdots & \vdots & \cdots \\ x_{N1}, u_{N1} & x_{N2}, u_{N2} & \cdots & x_{NM}, u_{NM} \end{bmatrix} \tag{2}$$

3.4.2. Normalization of the decision matrix element by using the equation below.

$$\left|\bar{x}_{ij}\right|_{mxn} = \frac{2x_{ij}}{\sum_{i=1}^{m} x_{ij} + \sum_{i=1}^{m} u_{ij}} \tag{3}$$

$$\left|\bar{u}_{ij}\right|_{mxn} = \frac{2u_{ij}}{\sum_{i=1}^{m} x_{ij} + \sum_{i=1}^{m} u_{ij}} \tag{4}$$

$$i = 1,2,\dots,N \ \ and \ \ j = 1,2,\dots,M.$$

i represent the alternatives and *j* represents the attributes

The normalized decision matrix is illustrated in the equation below:

$$X = \begin{bmatrix} \bar{x}_{11},\bar{u}_{11} & \bar{x}_{12},\bar{u}_{12} & \dots & \bar{x}_{1M},\bar{u}_{1M} \\ \bar{x}_{21},\bar{u}_{21} & \bar{x}_{22},\bar{u}_{22} & \vdots & \bar{x}_{2M},\bar{u}_{2M} \\ \dots & \dots & & \dots \\ \bar{x}_{N1},\bar{u}_{N1} & \bar{x}_{N2},\bar{u}_{N2} & \dots & \bar{x}_{NM},\bar{u}_{NM} \end{bmatrix} \tag{5}$$

3.4.3. Preparation of a normalized weighted $\hat{X}$decision matrix using the following equations:

$$\hat{x}_{ij} = \bar{x}_{ij} \ x \ q_i \tag{6}$$

$$\hat{u}_{ij} = \bar{u}_{ij} \ x \ q_j \tag{7}$$

$$i = 1, 2, \dots, N \ dan \ j = 1, 2, \dots, M$$

The weighted normalized decision matrix is shown below:

$$X = \begin{bmatrix} \hat{x}_{11},\hat{u}_{11} & \hat{x}_{12},\hat{u}_{12} & \dots & \hat{x}_{1M},\hat{u}_{1M} \\ \hat{x}_{21},\hat{u}_{21} & \hat{x}_{22},\hat{u}_{22} & \vdots & \hat{x}_{2M},\hat{u}_{2M} \\ \dots & \dots & & \dots \\ \hat{x}_{N1},\hat{u}_{N1} & \hat{x}_{N2},\hat{u}_{N2} & \dots & \hat{x}_{NM},\hat{u}_{NM} \end{bmatrix} \tag{8}$$

3.4.4. Evaluation of the number of weighted normalization values. The number of weighted normalization values for beneficial attributes was evaluated by use the equation below:

$$P_i = \frac{1}{2} \sum_{j=1}^{k} (\hat{x}_{ij} + \hat{u}_{ij}) \tag{9}$$

where k = the total number of beneficial attributes that will be maximized

3.4.5. Determination of the relative weights of each alternative denoted by Qj. The value of Qi was calculated by use the following equations.

$$R_{min} = \min_{i} R_i ; i = 1, 2, 3, \dots, N \tag{10}$$

$$Q_i = P_i + \ [(R_{min} \ \sum_i^M R_i)/(R_i \ \sum_i^M \left(\frac{R_{min}}{R_i}\right))] \tag{11}$$

$$Q_i = P_i + \ [(\sum_i^M R_i)/(R_i \ \sum_i^M \left(\frac{1}{R_i}\right))] \tag{12}$$

3.4.6. Calculation of the utility level of each alternative. Qj is the alternative significance obtained from equation above, and Qmax is the maximum relative significance of the value. The alternate rating can be determined based on utility rates calculated using the equation below.

$$N_i = (Q_i/Q_{\max} \ \ ) * 100\% \tag{13}$$

The results of weight calculations and device sequences are represented in table 4.

Tabel 4. Result of COPRAS

	Ultrasound Device				
	EA	**EB**	**EC**	**ED**	**EE**
Pi	0,1812	0,1690	0,1900	0,1925	0,1551
Ri	0,0207	0,0195	0,0243	0,0262	0,0213
1/Ri	48,3452	51,3668	41,0934	38,2265	46,9639
Qi	0,2051	0,1945	0,2103	0,2114	0,1783
Ni (%)	**97,04%**	**91,99%**	**99,50%**	**100,00%**	**84,36%**

Graphical display of the sequence of five alternative ultrasound devices based on the degree of utility is presented in figure 2 below.

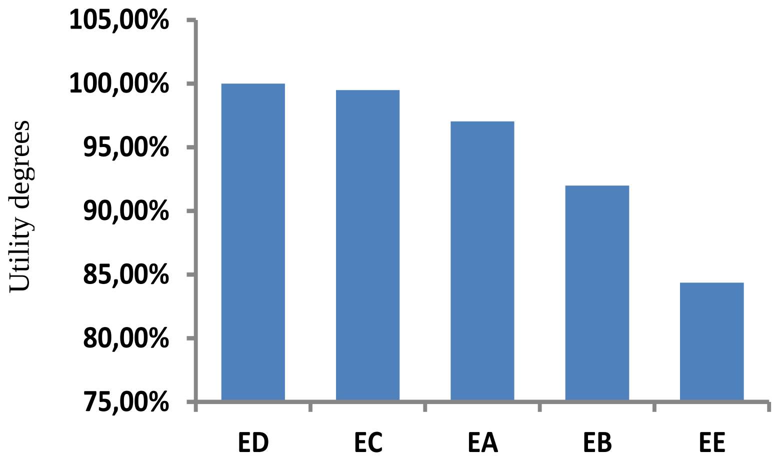

Figure 2. Sequences of ultrasound device

4. Conclusion

The five criteria with the greatest weight of the ANP fuzzy calculation for ultrasound device selection are the powerful transducers (C7-1), exchangeable components (C2-4), one probe license per year (C2-1), price (C1), and the size or width and length are minimum (C4-1). Transducers are an essential component of ultrasound devices and therefore strong transducers and one exchange license per year are two important criteria in ultrasound device selection. The criteria of ease of component exchange is also important because the price of ultrasound device components is relatively expensive so it will facilitate in facing the problem of ultrasound usage.

Based on the results of COPRAS use, alternate ultrasound sequences based on utility degrees ranging from the best are ED, EC, EA, EB and EE. So TMC clinic can choose the fourth alternative device (ED) as the best ultrasound device.

Finally the results of this study indicate that the use of fuzzy-ANP and COPRAS is appropriate and good for equipment or device selection.

5. References

[1] Margulis A R and Sunshine J H 2000 Radiology at the turn of the millennium *Radiology*. 214(1):15-23. DOI: 10.1148/radiology.214.1.r00ja4515

[2] Nikola Kadoić, Nina BReđep and Blaženka Divja 2017 Decision Making With The Analytic Network Process, https://bib.irb.hr/datoteka/888413.anp_sor17_nk_nbr_bd_finale.pdf

[3] Saaty T L and L G Vargas 2006 *Decisions Making With The Analytic Network Process*. (Pittsburgh: RWS Publications)

[4] Rao R V 2013 *Decision Making in the Manufacturing Environment Using Graph Theory and Fuzzy Multiple Attribute Decision Making Methods* (London: Springer-Verlag)

[5] Nguyen Huu-Tho, Dawal Siti Z, Md Nukman, Yusoff, and Aoyama Hideki 2013 *A Hybrid Approach for Fuzzy Multi-Attribute Decision Making in Machine Tool Selection With Consideration of the Interactions of Attributes* (Elsevier Expert Systems with Applications)

[6] Bowra Justin, Bass Dirk and Telfah Malek 2014 *How to Choose An Ultrasound Machine for Your Emergency Department* (Sydney: Avondale College Sydney Campus Library)

[7] Promentilla MAB, Furuichi T, Ishii K and Tanikawa N 2008 A fuzzy analytic network process for multi-criteria evaluation of contaminated site remedial counter measures. *Journal of Environmental Management* **88** (3), 479–495.