Textbook Selection Using Fuzzy PROMETHEE II Method

K. K. F. Yuen and T. O. Ting

Abstract—**This study proposes the Fuzzy-PROMETHEE method for the textbook selection. The triangular fuzzy number and ranking method are integrated into the PROMETHEE II method. The proposed method can handle the uncertainty in the decision making. An example demonstrates the usability and validity of the proposed method. As the transparent book selection policy is promoted in many institutions, this method can be realized as a platform that receives input, feedback and comments from various participating users.**

Index Terms—**Decision making, Fuzzy PROMETHEE, textbook selection.**

I. Introduction

Textbook serves as a tool, guidebook, reference and tutor in many high institutions [1]. Lecturers throughout the world depend heavily on the content of textbooks for module delivery [2]. Therefore, textbook selection has been one of the important tasks for the faculty/school in high institutions. Research has been carried out to evaluate different textbooks at some institutions to assist lecturers in selecting a proper textbook [3]. However, this textbook evaluation is not a common practice in tertiary institutions. Hence, there is no surprise that there exists no proper process when acquiring or readopting a textbook in relevant modules. There is no indication of patterns on how textbook selection and the exact role of textbooks in classroom. However, there is one thing that is common – a majority of instructors prefer to have a textbook that would best meet their students' needs and become a good resource for class activities such as case study analysis, problem discussion and tutorial. We realize an efficient textbook selection with the assistant of the Fuzzy PROMETHEE method. This method is described below.

PROMETHEE (Preference Ranking Organization METHod for Enriching Evaluations) was firstly developed by Brans in 1982 at the conference [4], and then further developed as a family [5]. PROMETHEE I deals with a partial preorder, PROMETHEE II deals with a complete preorder, PROMETHEE III deals with an interval order emphasizing indifference, PROMETHEE IV deals with continuous set of possible alternatives, PROMETHEE V supports the optimization under constraints and PROMETHEE VI is a representation of the human brain. [6] reviewed a number of PROMETHEE's applications including the topics of environment management, hydrology and water management, business and financial management, chemistry, logistics and transportation, manufacturing and assembly, energy management, social, medicine, agriculture, education, design, government and sports. In [5], Brans combined the fuzzy set theory [7] in the form from [8], and the ranking method [9] into PROMETHEE, named F-PROMETHEE. The idea is that the fuzzy decision matrix is "defuzzified" as a crisp decision matrix, which satisfies the use of PROMETHEE. This research chooses the fuzzy number in the convention form to PROMETHEE II for the textbook Selection Problem.

In the rest of this study, section 2 describes the steps for Fuzzy PROMETHEE II. Section 3 demonstrates the use of the fuzzy PROMETHEE II for textbook selection, and Conclusions and future study are given in Section 4.

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II. Fuzzy PROMETHEE II

There are four steps in Fuzzy PROMETHEE II. The details are as follows.

Step 1: Formulate a fuzzy decision matrix

A typical m by n fuzzy decision matrix is shown as below:

$$\begin{array}{c} \\ \\ \widehat{T}_1 \\ \vdots \\ \widehat{T}_i \\ \vdots \\ \widehat{T}_m \end{array} \begin{array}{c} \begin{array}{cccccc} (\widehat{w}_1 & \cdots & \widehat{w}_j & \cdots & \widehat{w}_n) \\ \widehat{c}_1 & \cdots & \widehat{c}_j & \cdots & \widehat{c}_n \end{array} \\ \begin{pmatrix} & & & & \\ & & & & \\ & & \widehat{r}_{ij} & & \\ & & & & \\ & & & & \end{pmatrix} \end{array} \tag{1}$$

$\widehat{c}_j \in \widehat{C}$ is a fuzzy positive criterion. The criterion is a maximum criterion if the decision maker prefers more value for this criterion. Otherwise, it is a minimum criterion. $\widehat{T}_i \in \widehat{T}$ is an fuzzy alternative. $\widehat{T}^*$ is the ideal fuzzy alternative from $\widehat{T}$. $\widehat{r}_{ij} \in \widehat{r}$ is the utility value. $\widehat{w}_j \in \widehat{W}$ is the fuzzy weight of $\widehat{c}_j$. In [10], Goumas and Lygerou used the fuzzy number in the form (η, a, b), which is equivalent to the conventional form of triangular fuzzy number (l, η, u) such that $(l, \eta, u) = (\eta - a, \eta, \eta + b)$ where *m-a* is the low boundary *l*, *m+b* is up boundary *u*, and η is the modal value. This paper uses the conventional form (l, η, u) as a fuzzy number.

Step 2: Index fuzzy numbers in the fuzzy decision matrix

The fuzzy number in the fuzzy decision matrix can be "defuzzified" to the crisp number by the function:

$$I(l,\eta,u)=\frac{l+\eta+u}{3} \tag{2}$$

In other word, the above process converts a fuzzy decision matrix as a crisp decision matrix as follows:

$$\begin{array}{c} \begin{pmatrix} w_1 & \cdots & w_j & \cdots & w_n \end{pmatrix} \\ \begin{matrix} c_1 & \cdots & c_j & \cdots & c_n \end{matrix} \\ \begin{matrix} T_1 \\ \vdots \\ T_i \\ \vdots \\ T_m \end{matrix} \begin{pmatrix} & & & & \\ & & & & \\ & & r_{ij} & & \\ & & & & \\ & & & & \end{pmatrix} \end{array} \tag{3}$$

$c_j \in C$ is the positive criterion. $T_i \in T$ is the alternative. T^* is the ideal alternative from T. $r_{ij} \in r$ is the utility value. $w_j \in W$ is the weight of the criterion c_j. The cap removal from the fuzzy notations is crisp value.

Step 3: Calculate aggregated preference indices

$P_j(T_i,T_k)=P_j(d(T_i,T_k))=P_j(r_{ij}-r_{kj})$ is a preference function showing that how much T_i prefers to T_k with respect to c_j. According to Brans and Maraeschal [5], six types of preference functions $P(d)$'s are proposed. Goumas and Lygerou [10] chose V-Shape with indifference criterion as the preference function for their demonstration. (Please note that the function forms presented in [10] are only for maximium criteria.) This study chooses Gaussian Criterion function as the preference function and has the form:

$$P(d)=\begin{cases} 0 & d\le 0 \\ 1-e^{-\frac{d^2}{2s^2}} & d>0 \end{cases}$$, if the criterion is a maximum criterion. (4)

$$P(d)=\begin{cases} 0 & d\ge 0 \\ 1-e^{-\frac{d^2}{2s^2}} & d<0 \end{cases}$$, if the criterion is a minimum criterion. (5)

Aggregated preference index $\pi(T_i,T_k)$ expresses the degree of how T_i is preferred to T_k over all the criteria. The aggregated preference indices are of the form:

$$\pi(T_i,T_k)=\frac{\sum_{j=1}^{n}P_j(T_i,T_k)\cdot w_j}{\sum_{j=1}^{n}w_j},\ \forall T_i,T_k\in T \text{ and } i\ne k \tag{6}$$

Step 4: Calculate outranking flow

Each alternative T_i is facing (m-1) other alternatives in T. In order to rank the alternatives, the outranking flows are defined as follows.

The positive outranking flow is of the form:

$$\phi^+(T_i)=\sum_{k=1}^{m}\pi(T_i,T_k) \tag{7}$$

The negative outranking flow is of the form:

$$\phi^-(T_i)=\sum_{k=1}^{m}\pi(T_k,T_i) \tag{8}$$

The net outranking flow is applied and is of the form:

$$\phi(T_i)=\phi^+(T_i)-\phi^-(T_i),\ \forall i\in\{1,\ldots,m\} \tag{9}$$

The positive outranking flow expresses how an alternative T_i is outranking all the others. The higher $\phi^+(T_i)$ gives a better alternative. On the other hand, the negative outranking flow expresses how an alternative T_i is outranked by all the others. The lower $\phi^-(T_i)$ gives a better alternative. The higher $\phi(T_i)$ follows the better alternative.

III. Case Study

Choosing the right textbook is an essentially task in many institutions to ensure a quality teaching whilst there are many alternatives in the market. Textbooks also act as a vital reference and additional information source for participating students. Each semester, students are given the appropriate textbooks on the basis of the modules / subjects they undertake. In practice, one textbook will be allocated to a module taken and it is compulsory for students to have a textbook for all the modules taken. There are few discrepancies to the current policy on textbook:

- Students find it hard to understand the textbook provided.
- Some textbooks are left untouched by students for the whole semester.
- There exists no proper channel for students to feedback their comments concerning each textbook. Similarly, lecturers do not get thorough comments from students in their class.
- Some textbooks may even have the whole book in the form of e-book. Adopting e-book will be much cheaper compared to the current printed textbooks.
- Some textbooks are too heavy and students find it inconvenient to bring to class.

From the above discrepancies, it is evident that a new textbook selection process is required to overcome the current inefficiency of textbooks usage. This textbook selection has been done in the following process using F-PROMETHEE II.

Step 1: Formulate the fuzzy decision matrix

According to the investigation, five evaluation criteria are proposed for the evaluation.

1. *Content*: Readability, syllabus coverage, edition etc.
2. *Price*: Locally printed textbooks are much cheaper compared to international versions.
3. *Teaching Resources*: Powerpoint slides, tutorial questions and answers, website etc.
4. *Author Backgrounds*: Research works, experience, popularity etc.
5. *E-learning support*: Blackboard, Moodle, WebCT, Examview etc.

The weights and scores are given to alternatives with respect to all criteria in Table I.

TABLE I: FUZZY DECISION MAKING MATRIX FOR TEXTBOOK SELECTION

Criteria	C1	C2	C3	C4	C5
Value	Max.	Min.	Max.	Max.	Max.
s	5	-50	5	5	5
Weight	(9,10,11)	(9,10,11)	(9,10,11)	(6,7,8)	(4,5,6)
T1	(6,8,9)	(140,150,160)	(7,8,9)	(6,7,8)	(4,5,6)
T2	(7,9,10)	(189,199,209)	(8,9,9)	(6,7,8)	(4,5,6)
T3	(8,10,10)	(229,239,249)	(8,9,10)	(8,9,10)	(4,5,6)
T4	(9,10,11)	(390,400,410)	(9,10,11)	(9,10,11)	(9,10,11)

Step 2: Index fuzzy numbers in the fuzzy decision matrix

The fuzzy decision matrix is "defuzzified", by eq.(2), to the crisp decision shown in Table II.

TABLE II: DECISION MAKING MATRIX AFTER INDEXING

Criteria	C_1	C_2	C_3	C_4	C_5
Weight	10	10	10	7	5
T_1	7.667	150	8	7	5
T_2	8.667	199	8.667	7	5
T_3	9.333	236	9	9	5
T_4	10	299.333	10	10	10

Step 3: Calculate aggregated preference indices

With respect to the crisp decision matrix in the above step, the aggregated preference index matrix for the alternatives is shown in Table III. The Gaussian criterion is chosen for all criteria where the parameter *s* for each criterion is presented in Table I.

TABLE III: AGGREGATED PREFERENCE INDEX MATRIX

	T_1	T_2	T_3	T_4
T_1	0	0.091	0.184	0.235
T_2	0.007	0	0.057	0.206
T_3	0.030	0.015	0	0.131
T_4	0.117	0.091	0.057	0

Step 4: Calculate outranking flow

Using the aggregated preference indices, the positive, negative and net outranking flows are shown in Table 4. T_1 is the best textbook. The main reason is that the textbook is of the lowest price and satisfies most requirements, although it has no outstanding performance with respect to the other criteria.

TABLE IV: OUTRANKING FLOW INDICES AND RANK

	ϕ^+	ϕ^-	ϕ	*Rank*
T_1	0.510	0.154	0.356	*4
T_2	0.270	0.197	0.073	3
T_3	0.177	0.298	-0.121	2
T_4	0.265	0.573	-0.308	1

IV. CONCLUSION

This study proposes the fuzzy PROMETHEE II for the textbook selection process. This study modifies the structure of Fuzzy PROMETHEE in [10] in three aspects: representations of a fuzzy number and a ranking method as the convention way, use of fuzzy weights, as well as use of Gaussian criterion functions for both max. and min. criteria. Further study will explore detailed evaluation procedure for the textbook selection, and more comprehensive decision model, for example, integrating fuzzy Cognitive Network Process [11-13] into the further improved Fuzzy PROMETHEE method.

REFERENCES

[1] *Association for Supervision and Curriculum Development*, Education Update, vol. 39, no. 1, 1997.

[2] W. H. Schmidt, C. McKnight, S. Raizen, A Splintered Vision: An Investigation of U.S. Science and mathematics Education. Dordrecht, Netherlands, Kluwer, 1997.

[3] D. J. Cohen, "By the Book: Assessing the Place of Textbooks in U.S. Survey Courses," *The Journal of American History,* vol. 91, no. 4, pp.1405–1416, 2005.

[4] J. P. Brans, "Lingenierie de la decision. Elaboration dinstruments daide a la decision. Methode PROMETHEE," *In: R. Nadeau and M. Landry (eds.), Laide a la Decision: Nature, Instrument s et Perspectives Davenir,* Presses de Universite Laval, Qu ebec, Canada, pp. 183–214, 1982.

[5] J.-P. Brans, B. Mareschal. PROMETHEE Methods. in J. Figueira, S. Greco, M. Ehrgott, (eds.), Multiple Criteria Decision Analysis: State of the Art Surveys, International Series in Operations Research & Management Science. 2005, 78, chapter 5: 163-195.

[6] M. Behzadian, R. B. Kazemzadeh, A. Albadvi, and M. Aghdasi, "PROMETHEE: A comprehensive literature review on methodologies and applications," *European Journal of Operational Research,* vol. 200, no. 1, pp 198-215, 2010.

[7] D. Dubois and H. Prade, "Operations on fuzzy numbers," *International Journal of Systems Science,* vol. 9, pp. 613-626, 1978.

[8] L. A. Zadeh, "Fuzzy sets," *Information and Control,* vol. 8, pp. 338-353, 1965.

[9] R. R. Yager, "A procedure for ordering fuzzy subsets of the unit interval," *Information Science,* vol. 24, pp. 143-161, 1981.

[10] M. Goumas, V. Lygerou, "An extension of PROMETHEE method for decision making in fuzzy environment: Ranking of action energy exploitation projects," *European Journal of Operational Research,* vol. 123, pp. 347–357, 2000.

[11] K. K. F. Yuen, "The pairwise opposite matrix and its cognitive prioritization operators: the ideal alternatives of the pairwise reciprocal matrix and analytic prioritization operators", *Journal of the Operational Research Society,* vol. 63, pp. 322-338, 2012.

[12] K. K. F. Yuen, "The primitive cognitive network process: comparisons with the analytic hierarchy process," *International Journal of Information Technology & Decision Making,* vol. 10, no. 4, pp.659-680, 2011.

[13] K. K. F. Yuen, "Cognitive network process with fuzzy soft computing technique for collective decision aiding," *The Hong Kong Polytechnic University,* PhD thesis, 2009.