An Economic Based-Approach for Library System Selection

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ABSTRACT
Purpose of this paper: There are ways to rank competitive alternatives but ranking competing alternatives in terms of their overall performance with respect to some criterions in fuzzy environment is possible by the use of fuzzy TOPSIS methodology. Author discusses a fuzzy multi-criteria method based upon the fuzzy model and concepts of positive ideal and negative ideal solution points for solving problems with a group of multi decision makers. The fuzzy sets concepts are used to evaluate the performance of alternatives and the importanc
Design/methodology/approach: First Fuzzy TOPSIS methodology is fully described. Then a case study comprised of four main criteria and five alternatives is constructed and solved by the proposed method and the results are analyzed.
Findings: The TOPSIS methodology used in this article is able to grasp the ambiguity exists in the utilized information and the fuzziness appears in the human judgments and preferences. TOPSIS technique can easily produce satisfactory results, and hence stimulates creativity and the invention for developing new methods and alternative approacs
Practical implications (if applicable): This article is a very useful source of information for Fuzzy TOPSIS and decision making using more than one decision makers in fuzzy environment.

What is original/value of paper: Due to the fact that a better management of a system is related to the full understanding of the technologies implemented and the system under consideration, sufficient background on the methodologies are provided and a case study is developed and solved.

Keywords
Library management, Fuzzy TOPSIS, Fuzzy sets, system selection, Group decision making.

1. Introduction
Curran and Porter (2007) have proposed and outlined a library prototype that utilizes RFID to enhance and speed up the current customer book search and identification processes. The hardware used in the design and implementation of the prototypes are a laptop to host the server, a router to create the wireless network, a PDA to host the applications, RFID tags and an RFID reader to carry out the RFID communication. The user can search for a book on the shelf by entering the book information in any of the search criteria text boxes and pressing the Search button. The system has to search the database to return the appropriate book (Curran and Porter, 2007). The functionality and benefits offered by the RFID systems match the needs and areas of improvement for libraries. The development and evaluation of the library application has demonstrated that RFID can be successfully integrated into library systems.

When tracking and tracing items in an organization is not an easy task then tagging those items with RFID makes sense. Radio frequency identification (RFID) is a term used for technologies utilizing radio waves for identifying individual items automatically. The most common way is storing a serial number identifying a product and related information on a microchip attached to an antenna. RFID is used very similar to bar codes. It is designed to track items without requiring a line of sight. To read a bar code its lines had to stay in sight of the scanner to identify product correctly. RFID has received lots of commercial attentions in recent years especially in the areas of asset tracking, supply chain and library management. RFID is used in manufacturing to monitor the factory level (Labs, W. et al. 1998), in service sector (Lee et al. 2007), in product design (Repo, 2005), in managing restaurant (Ngai, 2007), in monitoring patients with diet problem (Hall, 2004), in pharmacy industry (Adams, 2007), for hospital social impacts assessment (Fisher et al. 2008), in logistic (Chow, et al. 2007, and Estifania, 2007), in pharmaceutical industry, and for monitoring and tracking live animals (Wismans, 1999). With regard to the library use of RFID, Seattle's RFID library project is the largest in the world, with Shenzhen's second. All RFID vendors in the library market offer a product with anti-collision (the ability to read several tags simultaneously). The actual speed at which this can be performed, and total number of tags that can be read does vary considerably (Curran, et al., 2007).

This research employs a fuzzy TOPSIS approach for evaluating RFID-based systems and then determining the most appropriate system among them. The practicality of the proposed model is demonstrated using a case study. The rest of this paper is structured as follows: Section 2 discusses fuzzy set and arithmetic operations. Fuzzy TOPSIS method is the topic of section 3. A case study is discussed in section 4. Management implementation is the topic of section 5. Author's conclusion is given last.

2. Fuzzy set and arithmetic operations

A fuzzy set is a set that is comprised of elements with the degree of membership of . When required data are quantitative then those can be expressed in terms of exact numbers but when research is being performed in the qualitative environment and the knowledge associated with that are vague and ambiguous data may not be expressed as exact numbers. Most often, researchers have claimed that managers cannot use an exact number to express their opinion about a situation instead a linguistic assessment is used to represent that specific numerical value (Herrera, 1999, 2000), and Kacprzyk (1986). As Zadeh (1965) has said, a realistic approach is the utilization of linguistic terms such as "true", "highly true", "more true", "less true", "false", "probably false", and… instead of real numbers. Hence, values can be expressed in linguistic terms which present more exact assessment of the situation (Zadeh, 1965, 1975). Often, a proper linguistic variable is being set up for the explanation of the ambiguity and vagueness associated with the domain of the problem. Then, the concept of the expression would be determined using fuzzy numbers defining through [1, 0] using a membership function. Since linguistic assessment is approximate, triangular and trapezoidal membership functions seem to be more appropriate for responding to the ambiguity of these assessments (Delgado et al., 1993).

While crisp data are inadequate to model the real life situations in MCDM, we apply linguistic variables to specifically describe the degrees of a criterion. In order to facilitate the making of subjective assessment by the decision makers (DM) using fuzzy numbers, two sets of linguistic terms are used for assessing criteria weights and performance rating on each qualitative criterion respectively. A linguistic variable is a variable which apply words or sentences in a natural or artificial language to describe its degree of value, and we use this kind of expression to compare each criteria by linguistic variables in a fuzzy environment as ‘‘extremely important", ‘‘very important", ‘‘important", ‘‘very unimportant", and ‘‘extremely unimportant" with respect to a fuzzy five level scale. More on fuzzy set and fuzzy arithmetic is given in appendix.

3. Fuzzy TOPSIS Algorithm

Prior to the description of the fuzzy TOPSIS algorithm it is highly recommended to describe the fundamental data type, decision matrix, those who are involved in the decision making process, variables, and then the steps necessary to go through to make a sound decision. A triangular fuzzy number (a, b, c) is one that can be shown by the figure presented in appendix. This algorithm is comprised of nine steps as are discussed one by one below.

Step 1 (Decision Matrix and Weight development)
The very first step of TOPSIS algorithm is the determination of the decision matrix. This matrix has m rows and n columns, where m represents the number of alternatives to be ranked, Ai, (i=1,.., m), and n represents the number of criterions that based on that the ranking will be based on C_j (j=1,…,n). In the model, it is assumed that there are K decision makers that subjectively assess the weighting vector of $W = (w_1, ..., w_n)$ and the decision matrix X={ ,i =1,2,…,m; and j=1,2,…,n}, using the linguistic terms described in table 1 and 2, below.

Table 1: Fuzzy linguistic terms and corresponding fuzzy numbers for each criterion

Importance	Abbreviation	Fuzzy Number
Very low	VL	(0, 0, 0.2)
Low	L	(0.05, 0.2, 0.35)
Medium low	ML	(0.2, 0.35, 0.5)
Medium	M	(0.35, 0.5, 0.65)
Medium high	MH	(0.5, 0.65, 0.8)
High	H	(0.65, 0.8, 0.95)
Very high	VH	(0.8, 1, 1)

Table 2: Fuzzy linguistic terms and corresponding fuzzy numbers for each alternative

Importance	Abbreviation	Fuzzy Number
Very poor	VP	(0, 0, 0.2)
Poor	P	(0.05, 0.2, 0.35)
Medium poor	MP	(0.2, 0.35, 0.5)
Fair	F	(0.35, 0.5, 0.65)
Medium good	MG	(0.5, 0.65, 0.8)
Good	G	(0.65, 0.8, 0.95)
Very good	VG	(0.8, 1, 1)

Taking alternatives A_i (i=1,…,m) and criterions C_j (j=1,…,n) into consideration, the decision matrix can be expressed as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \end{array}$$

Given the weighting vector W and decision matrix X, the objective of the problem is to rank all the alternatives by giving each of them an overall utility with respect to all selection criteria. The decision matrix as well as the weighting vector is originally expressed in terms of linguistic variables by decision makers. Using the triangular fuzzy numbers given in tables 1 and 2 equivalent tables of decision making and weight vector can be developed.

Step 2 (Normalization of decision matrix)
Before we can make any use of data provided in step 1 we need to develop a normalized decision matrix. Doing so, we convert all incommensurable criterions into unique and common sense numbers. The decision matrix must first be normalized so that the elements will be unit-free.

Step 3 (Weighted normalized decision matrix)
In this step, the weighted normalized decision matrix for the kth decision maker needs to be constructed.

Step 4 (Distances from PIS and NIS)
Two ideal solutions points known as positive ideal and negative ideal solution points are of highly concerned in the decision making process. The decision maker feels to stay away as far as possible from the negative ideal solution point and as close as possible to the positive ideal point. Although, these solution points are unreachable in reality they are of very concern and important to the decision maker. Therefore, the positive ideal solution shown by A* and negative ideal point shown by A^- should be determined.

Step 5 (Separation Measures)

Determine the separation measures of S_i^* and S_i^- to be used for calculating the closeness coefficient of C_i .

Step 6 (Relative closeness to the ideal)
The relative closeness to the ideal solution for each alternative is computed in accordance with the following formula:

$$C_i^- = \frac{S_i^-}{S_i^* + S_i^-}$$

Step 7 (Ranking of alternatives)
A set of alternatives can now be preference ranked according to the descending order of C_i^- , and the one with the maximum value of C_i^- is the best.

4. Case Study

For various reasons organizations are reluctant to adopt RFID as a part of their internal systems. This is because of uncertainty regarding the payoff that will (or might) result from the adoption (Reyes et al., 2006; Dutta et al., 2007). Central to this uncertainty are risks accompanying adoption that can be grouped into two broad areas – uncertainty with regard to the requirements and capabilities of the technology itself and uncertainty with regard to the effects of the technology on inter organizational relationships (Cannon et al., 2008). Due to the fact that at the present time RFID is still in its early stages of development and acceptance by the management of large and small companies there are many questions that are unanswered with regard to its actual or potential use.
With the analysis available in literature of RFID on library science (Kern, 2004; Butters, 2007; Yu, 2007; and Zare Mehrjerdi, 2010) it is concluded that the most appropriate types of alternatives that should be taken into consideration are those that relates RFID systems and barcode systems together. This is because of the power of the barcode and its popularity at the present time. Barcode is going to

stay for a long time and will not disappear overnight. This is because the barcode system is less expensive to setup, manage, work with, and it is in use all around the world. Hence, this research is up to putting to vote the following RFID-based-mixed-systems as alternative to the team of decision makers:

1. System type 1: a system with 100 percent RFID power and 0% barcode capability
2. System type 2: a system with 70 percent RFID power and 30% barcode capability
3. System type 3: a system with 60 percent RFID power and 40% barcode capability
4. System type 4: a system with 50 percent RFID power and 50% barcode capability
5. System type 5: a system with 40 percent RFID power and 60% barcode capability

This means stage by stage conversion from barcode system into the RFID-based system which gives sufficient time to both producers
and consumers to prepare their own RFID-based system for service. The criterions that are of the highest preference to most management through the entire industries are:

1. The hardware and software costs
2. The contribution that system can have on the organization
3. Changing the current situation for a better one
4. Expert reliability on the RFID-based system support.

In this section, a system selection problem is under review where the most appropriate one need to be identified using a group of three decision makers of DM1, DM2, and DM3. For this purpose, a list containing five RFID-based systems as shown in table 3 are determined, related criterions are identified and passed to a team of three decision makers. Each decision maker identifies the importance level of each criterion using the fuzzy linguistic terms given in table 1. To determine the decision matrix, the fuzzy linguistic terms provided in table 2 are used by the decision makers. More details on the criterions used and the alternative systems under study are given below. Linguistic terms and fuzzy numbers used in the following sections are those provided in tables 1 and 2.

4.1 Alternative Systems:

Five RFID-based systems starting with a system of 100 percent RFID and 0% barcode features and ending with a system of 40% RFID and 60% barcode features are under consideration here.

Table 3: Features of five alternative systems

Alternatives	RFID-based systems	Barcode based system
System 1 (A1)	100%	0%
System 2 (A2)	70%	30%
System 3 (A3)	60%	40%
System 4 (A4)	50%	50%
System 5 (A5)	40%	60%

4. 2 Criterions:

The criterions used in this study are:

1. The hardware and software costs (C1)
2. The contribution that system can have on the organization (C2)
3. Changing the current situation for a better one (C3)
4. Expert reliability on the RFID-based system support (C4)

4.3 Criterion classification

These four criterions can be classified into two categories of benefit type and cost type as shown below:

$$B = \left\{ \begin{matrix} Benefit \\ Type \\ criterion \end{matrix} \right\} = \{\text{Contribution, Level of change, Expert reliability}\}$$

$$C = \left\{ \begin{matrix} Cost \\ Type \\ Criterion \end{matrix} \right\} = \{\text{Costs of hardware and software}\}$$

4.4 Solution details and discussion

Three decision makers DM1, DM2, and DM3 form a committee to act as decision makers in this case study. Each decision maker uses their own judgment to determine the level of importance of each of the criterion with respect to the evaluations that they want to determine.

Table 4: Level of importance of each criterion

Criterions	Decision maker 1 (DM1)	Decision maker 2 (DM2)	Decision maker 3 (DM3)
Cost of H&S (C1)	VH	H	MH
Contributions (C2)	H	VH	VH
Level of change (C3)	MH	MH	H
Expert reliability (C4)	H	VH	VH

Next, it was asked the decision maker committee to rate systems (alternatives) with respect to the criterion that is identified for the evaluation purposes. The results of their effort are summarized in the table given below:

Table 5: Decision makers rating of alternatives with respect criterions

Decision makers	Alternatives	Costs of H&S (C1)	Contribution (C2	Level of Change (C3)	Expert reliability (C4)
DM 1	System 1	P	VG	VG	MP
	System 2	P	VG	G	MP
	System 3	MP	G	G	MP
	System 4	F	MG	MG	F
	System 5	MG	MG	MG	F
DM 2	System 1	P	G	VG	P
	System 2	P	G	VG	MP
	System 3	MP	MG	G	MP
	System 4	F	MG	F	F
	System 5	MG	F	F	F
DM 3	System 1	P	MP	MG	P
	System 2	P	F	MG	P
	System 3	F	MG	F	P
	System 4	MG	G	F	MP
	System 5	G	G	F	MP

The decision matrix D with x_{ij} elements is given by table 6.

Table 6: Decision matrix

	Benefits	Change	Reliability	Costs
x_{ij}	(0.20, 0.35, 0.5)	(0.50,0.65,0.80)	(0.05,0.2,0.35)	(0.05,0.2,0.35)
	(0.35,0.50,0.65)	(0.50,0.65,0.80)	(0.05,0.2,0.35)	(0.05,0.2,0.35)
	(0.50,0.65,0.80)	(0.35,0.50,0.65)	(0.05,0.20,0.35)	(0.35,0.50,0.65)
	(0.65,0.80,0.95)	(0.35, 0.5,0.65	(0.20,0.35,0.50)	(0.50,0.65,0.80)
	(0.65,0.80,0.35)	(0.35,0.50,0.65)	(0.2,0.35,0.5)	(0.65,0.80,0.95)

Table 7: weighted normalized decision matrix

	Benefits	Change	Reliability	Costs
v_{ij}	(0.17,0.37,0.53)	(0.34,0.55,0.80)	(0.04,0.21,0.37)	(0.07,0.16, 0.8)
	(0.29,0.53,0.68)	(0.34,0.55,0.80)	(0.04,0.21,0.37)	(0.07,0.16, 0.8)
	(0.42,0.68,0.84)	(0.24,0.42,0.65)	(0.04,0.21,0.37)	(0.04,0.07,0.11)
	(0.55,0.84, 1)	(0.24,0.42,0.65)	(0.17,0.37,0.53)	(0.03,0.05,0.08)
	(0.55,0.84, 1)	(0.24,0.42,0.65)	(0.17,0.37,0.53)	(0.03,0.04,0.06)

Table 8: Distance from positive and negative solution

	DM1	DM1		DM2	DM2		DM3	DM3
Alterna-tives	d^{1-}	d^{1+}		d^{2-}	d^{2+}		d^{3-}	d^{3+}
A1	1.680	1.463	A1	1.740	1.543	A1	1.296	1.786
A2	1.614	1.535	A2	1.866	1.415	A2	1.429	1.648
A3	1.105	1.200	A3	1.256	1.191	A3	1.061	1.220
A4	0.951	1.214	A4	1.146	1.179	A4	1.317	0.963
A5	0.923	1.186	A5	0.994	1.278	A5	1.305	0.951

Table 9: Combined distances by alternatives

Alternatives		Sum	CCI	Ranking
A1	1.263	2.607	0.4844	3
A2	1.435	2.629	0.5459	1
A3	0.491	1.072	0.4580	4
A4	0.478	0.937	0.5101	2
A5	0.399	0.879	0.4536	5

Table 10: relative closeness to the ideal solution by alternatives

Alternatives			Sum
A1	1.263	1.344	2.607
A2	1.435	1.194	2.629
A3	0.491	0.581	1.072
A4	0.478	0.459	0.937
A5	0.399	0.480	0.879

From table 10 we conclude that A2 > A4 > A1 > A3 > A5. This means that an RFID-based system having 70% RFID feature and 30% barcode feature are the most appropriate one as far as these groups of three decisions are concerned. Due to the facts that human judgments may change from one decision maker to another therefore another group of decision makers may reach to a different set of solution.

5.Management Implication

With huge benefits that RFID-based systems can provide, management can offer to its patrons and community the advantages of having in their hands: (1) speedy book finding; (2) tracking misplaced items; (3) high security; (4) aiding disabled people; (5) self-checkout and returning materials; and (6) increasing productivity. Managements are in need of having appropriate decision making tools for selecting the best possible choice among the set of alternatives given to them. TOPSIS is an acceptable management tool that can be used in multi criterion decision making and as it is shown in this article it is highly suitable for dealing with group decision making problems in library management too.

6. Conclusion

This paper is written based upon researches and observations from scientific journals and reports. Due to the fact that a better management of a library system is related to the full understanding of the technologies implemented and the system under consideration, some backgrounds on the radio frequency identification technology and its benefits and risks are provided. After discussing the basic concepts of fuzzy TOPSIS a sample case study comprised of a situation with five types of systems under study, where only one of them should be selected for final use by the organization, is discussed. Due to the fact that the proposed methodology allows management to look into available systems taking the judgment of some decision makers to identify the most appropriate one, this study makes a significant contribution to the literature of library management.

Appendix

A real fuzzy number A is described as a fuzzy subset of the real line R with member function f_A that represents uncertainty. A membership function is defined from universe of discourse to [0, 1] (see Fig. 1). A triangular fuzzy number can be defined as a triplet (a, b, c). Therefore, a membership function of the fuzzy number A is defined as

$$f_A = \begin{cases} 0, & x \leqslant a \\ \frac{x-a}{b-a}, & a \leqslant x \leqslant b \\ \frac{c-x}{c-b}, & b \leqslant x \leqslant c \\ 0, & x \leqslant c \end{cases}$$

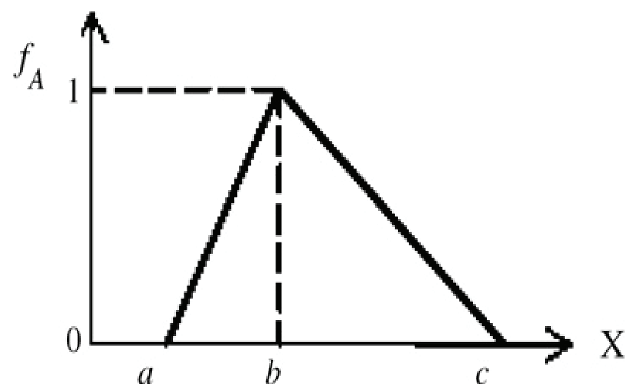

Figure 1: A representation of triangular fuzzy number with triplet (a, b, c)

Using this representation, we can do arithmetic operations on fuzzy numbers very simple and quick. With the notations given above the arithmetic operations of (+), (-), (x), and ( ) on fuzzy numbers are defined as follows:

$$(a_1, b_1, c_1) (+) (a_2, b_2, c_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$$

$$(a_1, b_1, c_1) (-) (a_2, b_2, c_2) = (a_1 - c_2, b_1 - b_2, c_1 + a_2)$$

$$(a_1, b_1, c_1) (x) (a_2, b_2, c_2) = (a_1 x a_2, b_1 x b_2, c_1 x c_2)$$

$$(a_1, b_1, c_1) (\div) (a_2, b_2, c_2) = (a_1 \div c_2, b_1 \div b_2, c_1 \div a_2)$$

The inversion of a fuzzy number and the multiplication of constant times a fuzzy number are done according to following formula:

$$(a_1, b_1, c_1)^{-1} = (\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1})$$

$$k \, (a_1, b_1, c_1) = (ka_1, kb_1, kc_1)$$

The distance between fuzzy numbers of and is calculated as below (Chen, 2000):

$$d(A_1, A_2) = \sqrt{(1/3)[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

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