OPTIMIZATION OF COTTON MIXING COST: A FUZZY LINEAR PROGRAMMING APPROACH

Subhasis Das[1]; **Anindya Ghosh**
Government College of Engineering & Textile Technology,
Department of Textile Technology, Berhampore, India
e-mail: [1]subhasis.tex@gmail.com

Abstract

This paper deals with the minimization of the cost for three types of cotton mixings suitable for the production of fine, medium and coarse yarns without impinging the required quality using the fuzzy linear programming, which is the amalgamation of fuzzy logic and classical linear programming. The findings of this work point out that the fuzzy linear programming attains the best solution of cotton mix in comparison with its classical version as well as the existing method followed in cotton spinning industry.

Introduction

The concept of fuzzy linear programming was first proposed by Bellman and Zadeh [1]. Thereafter, Zimmermann [2], Verdegay [3, 4], Chanas [5], Werners [6], Tan [7] etc. made significant contributions in the development of fuzzy linear programming. Elamvazuthi et al. [8] used fuzzy linear programming in production planning in textile industry.

Judicious mixing of different types of cotton fibres is an optimization problem for obtaining raw material with required quality at a minimum cost in the cotton spinning industries. In this work an attempt has been made to solve the cotton mixing problem using fuzzy linear programming approach. The case studies have been made on three types of cotton mixings suitable for the production of fine, medium and coarse yarns. The data for this problem are taken from the cotton spinning industry. In keeping with the traditional industrial practice, two varieties of cottons are considered for each type of mixing. A comparative study of the relative performances of fuzzy linear programming and its classical version is presented here. It also attempts to establish its effectiveness over the usual practice as followed by the cotton spinning industry.

1   Optimization of Cotton Mixing Cost

Cotton fibre mixings suitable for the production of fine, medium and coarse yarns are considered in this study, and the data were collected from the cotton spinning industry. For each type of mixing two varieties of cottons are used. The objective of this study is to determine the proportion of cottons for each type of mixing to achieve the best quality yarns at the lowest raw material cost. Judging from theory and a practical standpoint, four fibre properties, such as fibre bundle strength, upper half mean length (UHML), fibre fineness and short fibre content (SFC) are considered since they exert a strong influence on the yarn quality. Table 1 depicts the fibre properties and costs for different types of cottons.

Mixing type	Cottons used	Bundle strength (cN / tex)	UHML (mm)	Fineness (µg/inch)	Short fibre content (%)	Cost / 100 Kg cottons (USD)
Fine	ULTIMA	34.5	31.80	3.9	20.90	394.40
	PIMA	38.8	34.30	4.2	12.50	367.00
Medium	DCH -32	39.1	35.12	4.2	16.10	291.40
	MCU-5	31.5	31.10	4.3	21.50	269.53
Coarse	J-34	32.1	28.73	4.8	19.70	268.80
	S-6	31.3	28.17	4.4	20.16	281.64

Source: Own

1.1 Fuzzy Linear Programming Approach

As the bundle strength and UHML are benefit criteria where higher values are desirable, and fineness and SFC are cost criteria where lower values are better, the problem for each type of cotton mixing can be formulated as the following fuzzy linear programming problem:

Minimize $\qquad\qquad\qquad\qquad c_1 x_1 + c_2 x_2 \qquad\qquad\qquad\qquad$ (mixing cost)

Subject to,

$$a_{11} x_1 + a_{12} x_2 \geq E_1 \qquad\qquad \text{(strength)}$$

$$a_{21} x_1 + a_{22} x_2 \geq E_2 \qquad\qquad \text{(UHML)}$$

$$\frac{x_1}{a_{31}} + \frac{x_2}{a_{32}} \geq \frac{1}{E_3} \qquad\qquad \text{(fineness)}$$

$$a_{41} x_1 + a_{42} x_2 \leq E_4 \qquad\qquad \text{(SFC)}$$

$$x_1 + x_2 = 1$$

$$x_1, x_2 \geq 0$$

where x_1 and x_2 are the proportions of two varieties of cottons, c_1 and c_2 are their corresponding costs, E_1, E_2, E_3 and E_4 represent the monotonically decreasing membership function for the constrains such as fibre bundle strength, UHML, fineness and SFC, respectively.

The objective functions and constraint equations for fine, medium and coarse cotton mixings are formulated in Table 2. The membership functions for the various constraints of a particular mixing are determined by translating our perception and experience from the available fibre data. The obvious equality constraint in the product mix problem is the sum of x_1 and x_2 equals to one. MATLAB 7.11 coding has been used to solve the problems.

Tab. 2: *Objective functions, fuzzy numbers and constraints of fuzzy linear programming for different cotton*

Mixing type	Fine	Medium	Coarse
Objective Function	$394.4x_1 + 367.0x_2$	$291.4x_1 + 269.53x_2$	$268.8x_1 + 281.64x_2$
E1	1 when $x \le 28.5$ $\dfrac{38.5 - x}{38.5 - 29.5}$ when $28.5 < x \le 38.5$ 0 when $38.5 \le x$	1 when $x \le 27.5$ $\dfrac{38.0 - x}{38.0 - 27.5}$ when $27.5 < x \le 38.0$ 0 when $38.0 \le x$	1 when $x \le 28.5$ $\dfrac{32.0 - x}{32.0 - 28.5}$ when $28.5 < x \le 32.0$ 0 when $32.0 < x$
E2	1 when $x \le 27.5$ $\dfrac{35.2 - x}{35.2 - 27.5}$ when $27.5 < x \le 35.2$ 0 when $35.2 \le x$	1 when $x \le 27.5$ $\dfrac{35.0 - x}{35.0 - 27.5}$ when $27.5 < x \le 35.0$ 0 when $35.0 < x$	1 when $x \le 26.5$ $\dfrac{29.0 - x}{29.0 - 26.5}$ when $26.5 < x \le 29.0$ 0 when $29.0 < x$
E3	1 when $\dfrac{1}{x} \le \dfrac{1}{4.3}$ $\dfrac{\frac{1}{3.5} - \frac{1}{x}}{\frac{1}{3.5} - \frac{1}{4.3}}$ when $\dfrac{1}{4.3} < \dfrac{1}{x} \le \dfrac{1}{3.5}$ 0 when $\dfrac{1}{3.5} < \dfrac{1}{x}$	1 when $\dfrac{1}{x} \le \dfrac{1}{4.8}$ $\dfrac{\frac{1}{3.7} - \frac{1}{x}}{\frac{1}{3.7} - \frac{1}{4.8}}$ when $\dfrac{1}{4.8} < \dfrac{1}{x} \le \dfrac{1}{3.7}$ 0 when $\dfrac{1}{3.7} < \dfrac{1}{x}$	1 when $\dfrac{1}{x} \le \dfrac{1}{4.9}$ $\dfrac{\frac{1}{3.9} - \frac{1}{x}}{\frac{1}{3.9} - \frac{1}{4.9}}$ when $\dfrac{1}{4.9} < \dfrac{1}{x} \le \dfrac{1}{3.9}$ 0 when $\dfrac{1}{3.9} < \dfrac{1}{x}$
E4	1 when $x \le 10.0$ $\dfrac{16.0 - x}{16.0 - 10.0}$ when $10.0 < x \le 16.0$ 0 when $16.0 < x$	1 when $x \le 15.5$ $\dfrac{20.5 - x}{20.5 - 15.5}$ when $15.5 < x \le 20.5$ 0 when $20.5 < x$	1 when $x \le 18.0$ $\dfrac{20.5 - x}{20.5 - 18.0}$ when $18.0 < x \le 20.5$ 0 when $20.5 < x$
Equality constraints	$x_1 + x_2 = 1$	$x_1 + x_2 = 1$	$x_1 + x_2 = 1$
Variable boundary	$x_1, x_2 \ge 0$	$x_1, x_2 \ge 0$	$x_1, x_2 \ge 0$

Source: Own

1.2 Linear Programming Approach

The same objective functions are also solved using the linear programming problem which is formulated as:

minimize
$$c_1 x_1 + c_2 x_2$$

subject to,

$$a_{11}x_1 + a_{12}x_2 \ge e_1 \qquad \text{(strength)}$$

$$a_{21}x_1 + a_{22}x_2 \ge e_2 \qquad \text{(UHML)}$$

$$\frac{x_1}{a_{31}} + \frac{x_2}{a_{32}} \ge \frac{1}{e_3} \qquad \text{(fineness)}$$

$$a_{41}x_1 + a_{42}x_2 \le e_4 \qquad \text{(SFC)}$$

$$x_1 + x_2 = 1$$

$$x_1, x_2 \ge 0$$

Constraints of linear programming problem for different cotton mixings are tabulated in Table 3.

Tab. 3: Constraints of linear programming problem for different cotton mixings

Mixing type		Fine	Medium	Coarse
Inequality constraints:	**Strength**	$34.5x_1 + 38.8x_2 \geq 36.5$	$39.1x_1 + 31.5x_2 \geq 35.0$	$32.1x_1 + 31.3x_2 \geq 31.6$
	UHML	$31.8x_1 + 34.3x_2 \geq 33.1$	$35.12x_1 + 31.1x_2 \geq 33.1$	$28.73x_1 + 28.17x_2 \geq 28.1$
	Fineness	$\frac{x_1}{3.9} + \frac{x_2}{4.2} \geq \frac{1}{4.1}$	$\frac{x_1}{4.2} + \frac{x_2}{4.3} \geq \frac{1}{4.25}$	$\frac{x_1}{4.8} + \frac{x_2}{4.4} \geq \frac{1}{4.6}$
	SFC	$20.9x_1 + 12.5x_2 \leq 17.0$	$16.1x_1 + 21.5x_2 \leq 18.5$	$19.7x_1 + 20.16x_2 \leq 20.5$
Equality constraints		$x_1 + x_2 = 1$	$x_1 + x_2 = 1$	$x_1 + x_2 = 1$
Variable boundary		$x_1, x_2 \geq 0$	$x_1, x_2 \geq 0$	$x_1, x_2 \geq 0$

Source: Own

The performance of fuzzy linear programming for optimizing cotton mixing cost has been compared with that of linear programming vis-à-vis the existing mill practice. Table 4 illustrates the optimum proportion of cotton mixing as well as the mixing cost as obtained by different approaches.

Tab. 4: Mixing cost as obtained by different method

Mixing type	Cottons used	Industry practice		Linear programming		Fuzzy linear programming	
		Mixing proportion	Mixing cost ($/100kg)	Mixing proportion	Mixing cost ($/100kg)	Mixing proportion	Mixing cost ($/100kg)
Fine	ULTIMA/PIMA	50/50	380.70	32/68	375.76	27/73	374.73
Medium	DCH-32/ MCU-5	60/40	282.65	56/44	281.68	37/63	277.53
Coarse	J-34/S-6	50/50	275.22	52/48	274.93	81/19	271.29

Source: Own

The obtained properties of three types of cotton mixings solved by both fuzzy linear programming and linear programming are given in Table 5. It is observed from Tables 4 and 5 that the fuzzy linear programming invariably provides the best solution of the mixing proportion by fulfilling the condition of all constraints to ensure the least mixing cost. As an example, it is evident from Table 4 that in the case of fine mixing, the mixing cost per 100 kg is reduced from $380.70 to $375.76 while the problem is solved by linear programming and the mixing cost is further curbed down to $374.73 while it is solved by fuzzy linear programming. It thus follows that a mix of 32/68 of ULTIMA and PIMA cottons as obtained by linear programming produces a cheaper mixing than the 50/50 mix as practiced by the mill for a fine mixing, further a mix of 27/73 as obtained by the fuzzy linear programming yields a minimum mixing cost.

Tab. 5: Obtained properties of the cotton mixing

	Mixing type	Bundle strength (cN / tex)	Upper half mean length (mm)	Fineness (micronaire value)	SFC (%)
Fuzzy linear programming	**Fine**	37.66	33.67	4.12	14.79
	Medium	34.28	32.57	4.26	19.53
	Coarse	31.94	28.62	4.72	19.79
Linear programming	**Fine**	37.44	33.53	4.10	15.16
	Medium	35.72	33.33	4.24	18.50
	Coarse	31.72	28.46	4.60	19.92

Source: Own

A similar kind of observation is noted in the case of medium and coarse cotton mixings as shown in Table 4. The dominance of fuzzy linear programming for the cotton mixing problem may be attributable to its ability of handling the situation where there are no exact defined boundaries for the inequality constraints. For example, a spinner often uses the terms such as low and high to assess the fibre strength, length, fineness and SFC etc., however these terms do not constitute a well-defined boundary. All these fibre properties have approximate boundaries rather than exact boundaries. In addition, the membership functions for the various constraints could be developed by deciphering the experience of a spinner which renders a better utilization of the fibre properties needed for a particular mixing. Therefore, fuzzy linear programming satisfies both the goal and constraints with a maximum degree.

Conclusion

Fuzzy linear programming is used to optimize the raw material cost pertaining to three cotton mixings suitable for the production of fine, medium and coarse yarns. As per frequently followed industrial practice, two varieties of cottons are considered for each type of mixing. The solution obtained by fuzzy linear programming for the cotton mixing problem has been compared with that of linear programming as well as the existing system as practised by the cotton spinning industry. Fuzzy linear programming emerges as the most potent approach in this regard for all types of mixings followed by the linear programming. Fuzzy linear programming can enable to handle the imprecision that is present in the inequality constraints of fibre strength, length, fineness and SFC. A diminutive reduction in the raw material cost per 100 kg by retaining the fibre quality at a requisite level may lead to a considerable amount of economic gain to the cotton spinning industry. Therefore, the fuzzy linear programming approach of selection of the cotton mix has an enormous scope for industrial acceptance.

Literature

[1] BELLMAN, R. E.; ZADEH, L.A.: Decision Making in a Fuzzy Environment. *Management Science*. 1970, 17, 141-164.

[2] ZIMMERMANN, H.J.: *Fuzzy Sets & Systems*. 1978, 1, 45-55.

[3] VERDEGAY, J. L.: Fuzzy mathematical programming. In: Gupta, M. M. and Sanchez, E. (eds.) *Fuzzy Information and Decision Processes*. Amsterdam, 1982.

[4] VERDEGAY, J. L.: *Fuzzy Sets & Systems*. 1984, 1, 131-141.

[5] CHANAS, S.: *Fuzzy sets & Systems*. 1983, 11, 243-251.

[6] WERNERS, B.: *European Journal of Operations Research*. 1987, 31, 342-349.

[7] TAN, R. R.: *Environmental Modeling & Software*. 2005, 20, 1343-1346.

[8] ELAMVAZUTHI, I.; GANESAN, T.; VASANT, P.; WEBB, F. J.: *International Journal of Computer Science and Information Security*. 2009, 6, 238-243.

OPTIMALIZACE CENY BAVLNĚNÝCH SMĚSÍ: PŘÍSTUP FUZZY LINEÁRNÍHO PROGRAMOVÁNÍ

Tento článek se zabývá minimalizací nákladů u tří typů bavlněných směsí vhodných pro výrobu jemné, střední a hrubé příze, aniž by byla ohrožena požadovaná kvalita, pomocí tzv. fuzzy lineárního programování, které je sloučením fuzzy logiky a klasického lineárního programování. Závěr této práce poukazuje na to, že fuzzy lineární programování dosahuje u bavlněných směsí lepšího výsledku ve srovnání s klasickou verzí, jakož i se stávajícími metodami používanými při průmyslovém předení bavlny.

KOSTENOPTIMIERUNG FÜR BAUMWOLLMISCHUNGEN: ANSATZ DER FUZZY LINEARE PROGRAMMIERUNG

Dieser Artikel befasst sich mit der Kostenminimierung bei drei Typen von Baumwollmischungen bei gleichbleibender Qualität, die zur Herstellung feiner, mittlerer und grober Garne geeignet sind. Dies geschieht mit Hilfe des so genannten Fuzzy Lineare Programmierung, welches in einem Zusammenschluss von Fuzzy-Logik und dem klassischen linearen Programmieren besteht. Die Ergebnisse dieser Arbeit zeigen, dass das Fuzzy Lineare Programmierung bei Baumwollmischungen im Vergleich mit der klassischen Version und mit den bestehenden, beim industriellen Verspinnen der Baumwolle angewandten Methoden bessere Ergebnisse aufweist.

OPTYMALIZACJA CENY MIESZANEK BAWEŁNY: ZASTOSOWANIE ROZMYTEGO PROGRAMOWANIA LINIOWEGO

Niniejszy artykuł poświęcony jest zagadnieniu minimalizacji kosztów w przypadku trzech rodzajów mieszanek bawełny nadających się do produkcji cienkiej, średniej i grubej przędzy przy zachowaniu wymaganej jakości, z zastosowaniem metody tzw. rozmytego programowania liniowego (fuzzy linear programming), która jest połączeniem logiki rozmytej i klasycznego programowania liniowego. W zakończniu niniejszego opracowania wskazano, że rozmyte programowanie liniowe daje w przypadku mieszanek bawełny lepsze efekty w porównaniu z wersją klasyczną, jak i istniejącymi metodami stosowanymi w przemysłowym przędzeniu bawełny.