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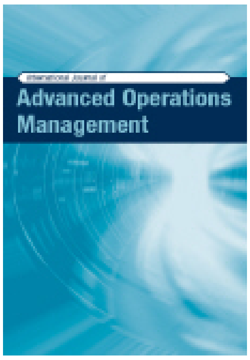

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Application of lexicographic goal programming technique to tackle production planning problem in the dairy manufacturing sector

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Abstract: Dairy manufacturing sectors are everywhere, and as such, this manufacturing sector has a mammoth influence on the planet. It has been illustrated as a leading provincial activity toward the economic development of numerous countries. These dairy manufacturing sectors usually face a lot of problems in production planning while producing different varieties of products. One of the traditional approaches to encountering production planning problems is to develop mathematical modelling as a decision support tool. Hereby, in this study, the lexicographic goal programming model is developed in the dairy manufacturing sector to tackle the production planning problem. This model aims to find the optimal production with the minimal available requirements. A case study is presented to illustrate this model in the production process. The important results are drawn by standard computer software packages. The obtained results show that all the desired goals in the dairy manufacturing sector are achieved.

Keywords: mathematical modelling; decision support system; lexicographic goal programming; dairy manufacturing sector; production planning.

JEL codes: 90C29.

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1 Introduction

In agriculture, the dairy manufacturing sector of India plays a vigorous factor, it leads to a positive effect on the livelihood of at least two-thirds of the rural population (Saran et al., 2020). It also powerfully impacts employment generation and health, establishing as a mobile bank for the said farmers and influencing on the enduring welfare of society. In rural areas, livestock is mentioned as one of the vigorous factors in the economy to provide income for various families. The dairy sector is considered an effective tool for enhancing the economic situations of rural families especially those of marginal and small farmers and landless agricultural labourers. Dairy's role in providing not only subordinate livelihood and nutritional ethics but also is a source of organic composts and drought power.

India's name is recorded amongst the largest milk producer countries and in 2018, India accounted for at least 22% of the total world's milk production (UN's Food and Agriculture Organization, 2019). According to an economic survey, milk production in India has grown by 35.61% throughout the last six years to 198.4 million tonnes in 2019–2020. Also, the survey concluded that milk production in India has increased to 198.5 million tonnes in 2019–2020 from 146.3 million tonnes in 2014–2015 (*Economic Times*, 2021). The survey also reveals that according to the study conducted by the National Dairy Development Board on the demand for milk, the predictable demand for milk and milk products at all Indian levels is 266.5 million tonnes for 2030.

The milk manufacturing sector is one of the foremost provincial economic activities of most countries. In dairy manufacturing processing, the rapid demand for good and quality products forces organisations to carefully plan and schedule their production process (Burke et al., 2018). In the dairy manufacturing sector, production planning problems can be sorted out by management science. Management science within the milk industry problem is particularly needed to assist production planning and the main focus of these dairy sectors is on operational planning as the required raw milk will be expired in one or two days which is why managers have to consume almost all available raw materials and have to find the foremost production plan (Leewattanayingyong and Ritvirool, 2007). The usual problems arising in the dairy manufacturing system are the concerned allocation of different dairy products to fulfil the customers' demand at a determined profit. Thus, there is a strong need to find the most valuable decision tool to frame the milk manufacturing production plan so that the maximum profit would be attained.

Dairies face a lot of usual problems, especially in planning and scheduling problems of make and pack production while producing different varieties of dairy products (Sel et al., 2017). As in the dairy sector, various desired goals are to be set, but in many important real-world decision-making situations, it may not be easy to reduce all such goals into a single objective. With the help of good and proper production planning, a production system attains success. There are some traditional ways to overcome such difficulties but mathematical programming plays an effective role in tackling these kinds of problems in the production process. In this study, the lexicographic goal programming model is used to encounter these kinds of problems. In milk production, the input-output connection has been studied and the associated covering cost of milk production is impartially well established.

Goal programming is the foremost technique and has been widely used in the field of operation research (OR). Charnes and Cooper (1961) were the first, who develop the concept of goal programming. The solution tactic of this technique has been also formulated by Ijiri (1965), Lee (1972), Ignizio (1976), etc. In the goal programming approach, whether the favourable goals are completely realistic or else, an objective will be specified in which the firm or organisation are in a situation to get the delightful solution with the help of optimisation drawn by the goal programming (Orumie and Ebong, 2014). Hereby, it can be concluded that the foremost motive of this goal programming technique is to diminish the deviation of each definite goal level (Jones and Tamiz, 2010). Actual target achievement has been achieved if the undesirable target deviation is reduced to zero. The key variation between the linear programming technique and goal programming technique is the occurrence of several objectives, i.e., linear programming has to minimise or maximise (optimise) a single objective while goal programming has several objectives to achieve.

The remainder of this paper is structured as follows. Section 2 provides an overview of some recent works in the area of lexicographic goal programming and the dairy production sector. The methodology and mathematical formulation of lexicographic goal programming are described in Section 3. The framework of the investigated dairy production planning problem is described in Section 4. Section 5 delves into the analysis of the results. Section 6 is concerned with discussion of the obtained results. The main conclusions and future study directions are presented in Section 7.

2 Review of literature

Several research studies have investigated and developed the goal programming model to demonstrate distinct advantages in respective production sectors. The lexicographic goal programming technique can be used to tackle production planning challenges with multiple competing objectives at the same time. Charnes and Cooper first proposed the concept of gaol programming in 1961, and since then, other researchers have worked in this field. Singh et al. (2000) and Romero (2001) proposed extended lexicographic goal programming as a unifying technique. Leewattanayingyong and Ritvirool (2007) developed a mathematical technique for the milk manufacturing industry's problem. They introduced an integer linear programming technique for each case study to govern the optimal solution and tested the proposed technique by considering industrial cases. Subbaiah et al. (2007) formulated goal programming and fuzzy goal programming and mentioned a brief evaluation of product mix in the dairy manufacturing sector. Umanath (2008) formulated lexicographic goal programming for specific farming conditions to determine optimum agricultural farm strategies and block proposals in a multi-objective framework for enhancing manufacturing and income, and different farming desires with the existing resources.

Babaei et al. (2009) introduced the lexicographic goal programming approach to solving multi-objective decision-making problems by prioritising objectives while considering five criteria. Leung and Chan (2009) presented a pre-emptive goal programming approach for aggregate production planning problems having different operational constraints. Sharma et al. (2010) suggested a goal programming model for solving environmental risk production planning problems in dairy production systems. Behura (2011) studied that by emerging the priority-based goal programming model for a production planning problem, the decision can easily be made with the satisfaction of goals consulting to their relative importance. Dangwal et al. (2013) introduced a goal programming approach for fuzzy multi-objective linear fractional programming (MOLFP) problems with a tolerance limit inside a vague environment. They also used the linear goal programming technique to solve the problem efficiently by introducing the methodology of variable modification within a specified tolerance of the membership and non-membership goal connected with the fuzzy goal of the model in the solution process.

The mixed integer linear programming (MILP) model was formulated as the distinctive feature of dairy products and it was applied by many researchers in the planning and scheduling at the last stage of dairy processing, i.e., on the packaging stage (e.g., Mendez and Cerda, 2002; Entrup et al., 2005; Doganis and Sarimveis, 2007;

Amorim et al., 2011; Baumann and Trautmann, 2013; Bilgen and Dogan, 2015). Javanmard and Kandi (2011) formulated a MILP technique in a single milk manufacturing line of the Sala industry in Iran to obtain optimal manufacturing scheduling with standard constraints in manufacture scheduling. Sharma and Hada (2012) formulated a goal programming technique for monitoring and tackling such environmental threats to manufacturing making plans problem that consist of reducing damages and wastes within side the milk manufacturing sector and described the technique by considering the 'SARAS' dairy manufacturing sector in India.

Chang et al. (2012) proposed a revised multi-segment goal programming model by advocating certain aspects of the multi-segment goal programming model to help decision-makers who cannot anticipate either-or coefficient selection in practice. Gupta et al. (2013) studied the effectiveness of the genetic algorithm for the optimisation of the ration of Indian dairy cows with 10 litres of milk yield and considered nonlinear weighted sum goal programming formulation. Wankhade and Lunge (2014) study the influence of weight parameters on the solution set of pre-emptive weighted goal programming by conducting sensitivity analysis. Chaudhari et al. (2020) developed a hybrid genetic goal programming strategy to increase group effectiveness in manufacturing system cell formation difficulties. Haq et al. (2020) formulated a multi-objective production planning technique to minimise the production cost, maximise the profit and reduce the holing cost in a hardware firm. Al-Arjani and Alam (2021) established the lexicographic goal programming paradigm to build the bank's performance management.

In summary, it has been found that there is less implementation of multi-objective mathematical models in the planning problems of dairy sectors and the studies coping with perishability issues especially dairy production planning problems often specialise in the packaging of very last products however mostly forget about the processing stage in the dairy sector. Research on the make-and-pack manufacturing of dairy products, maximising the profit, diminishing the labour cost, minimising the raw materials and optimising the use of machine time simultaneously has been almost neglected. The originality of the current study lies in displaying the lexicographic goal programming model to encounter certain problems arising in the production of the dairy sector. As it may not be possible that all desired goals of the dairy sector are compatible, they probably would be conflicting. So, the lexicographic goal programming model will provide an opportunity for the decision-makers to satisfy the desired goals simultaneously at priority levels according to their importance. Furthermore, the novelty of this study is that this lexicographic goal programming model has not been investigated in the early stages of dairy production.

3 Mathematical formulation and analysis

Lexicographic goal programming is sometimes known as 'pre-emptive' goal programming. The availability of many priority levels differentiates the lexicographic goal programming approach from other goal modelling techniques (Jones and Tamiz, 2010). Every prioritisation level has certain undesirable deviations that must be reduced within restrictions. In lexicographic goal programming, the decision-maker should rank the original problem goals in order of priority. The method is then optimised by focusing as carefully as possible on one of the most essential goals before moving on to the next higher goal, and such to the least significant goal, i.e., the objective functions were being prioritised such that achievement of the first goal is even more vital than the achievement of the second goal, which is much more important than the achievement of the third goal, and so forth, whereby the optimal values of a greater priority goal is not ever disgraced by a lesser priority goal. The representation can be found in recent publications such as (Orumie and Ebong, 2014; Umanath, 2008; Malik et al., 2021) among others.

The following is the suggested lexicographic goal programming model:

Minimise

$$Z = \sum_{j=1}^{m} r_j \left(h_j^- + h_j^+ \right) \tag{1}$$

subject to

- goal constraints:

$$\sum_{i=1}^{n} C_{ji} x_i + h_j^- - h_j^+ = p_j \text{ for } j = 1, 2, 3, \ldots, m \tag{2}$$

- hard constraints:

$$\sum_{i=1}^{n} C_{ji} x_i \begin{pmatrix} \geq \\ = \\ \leq \end{pmatrix} p_j \text{ for } j = m+1, \ldots, m+g \tag{3}$$

$$x_i, h_j^-, h_j^+ \geq 0 \tag{4}$$

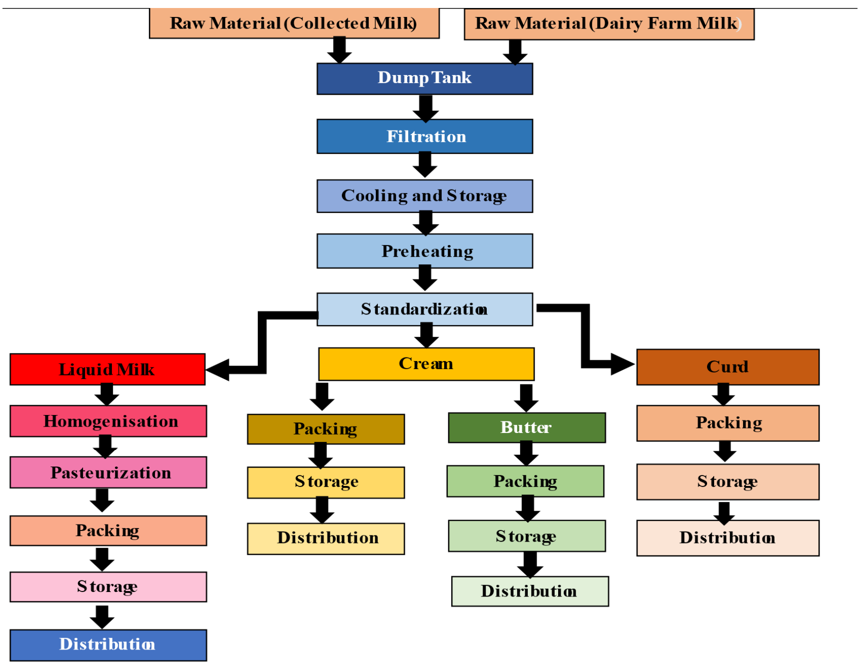
$$(j = 1, 2, 3, 4, \ldots, m), (i = 1, 2, 3, 4, \ldots, n)$$

where h_j^+ represents the positive deviation and is the amount of deviation above the target level of the j^{th} goal (overachievement); h_j^- denotes the negative deviation, which represents the amount of deviation below the goal level of the j^{th} goal (underachievement); hard constraints [equation (3)] are those constraints that are required to be satisfied; Z is the objective function or summation of all deviations; p_j represents the desired objective or target level of the j^{th} goal; x_i reflects the variables under consideration; C_{ji} represents the coefficients of the decision variables; g denotes the number of structural constraints; m is the number of goals; n is the number of decision variables; r_j is the pre-emptive factor/priority level assigned to each related goal in order of rank (i.e., $r_1 > r_2 > r_3 > \cdots > r_m$). The pre-emptive priority elements are ranked as per the priority assigned to a goal and are typically used when the desired goals have a clear priority ordering (Kumar, 2019).

4 Problem description and notations

To display the applicability and mathematical validation of the proposed technique in a small-sized dairy production sector manufacturing making plans problem is exemplified and the small-size manufacturing sector in India is taken as a case study. A set type of dairy products in the dairy manufacturing process is considered a descriptive case. The data is collected in the form of primary and secondary. The combination of a collection stage, processing unit and several packaging lines are included in the production sector. The processing of dairy products starts with the primary production, collection and reception of milk. The total cost, sale price and profit of each required product are given in Table 1. The different types of costs that the dairy sector is spending are illustrated in Table 2. The aspiration level of the products is shown in Table 3. The available quantity of resources is given in Table 4. The general processing of the dairy manufacturing sector is shown in Figure 1.

Figure 1 Flow diagram of a milk processing unit (see online version for colours)

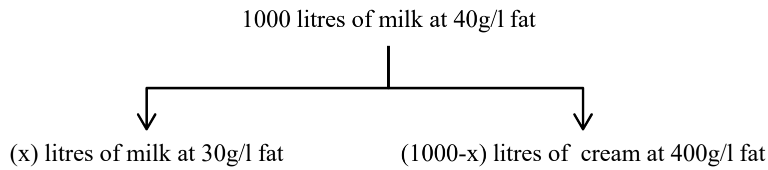


The standardisation procedure has been carried out for several products in order to determine the raw milk utilisation of these products and how much of numerous desired products with variable fat contents would be created from the whole milk, as shown below.

4.1 Standardisation

4.1.1 Toned milk (35 g fat) making

If the whole milk acquired outdoor and constituted of the dairy farm incorporates 40 g of fats per litre, and the toned milk must be standardised to the fats content material of 30 g per litre then the subsequent stability is obtained:



$$1000 \times 40 = 30x + 400(1000 - x)$$

$$40000 = 30x + 400000 - 400x$$

$$370x = 360000$$

$$x = 972.97 \text{ litres}$$

Therefore, 972.97 litres of milk comprising 30 g/litre of fat and 27.07 litres of cream with a fats content material of 400 g/litre will be produced from 1,000 litres of milk with a fats content material of 40 g/litre.

4.1.2 Skimmed milk (26 g fat), cheese and butter production

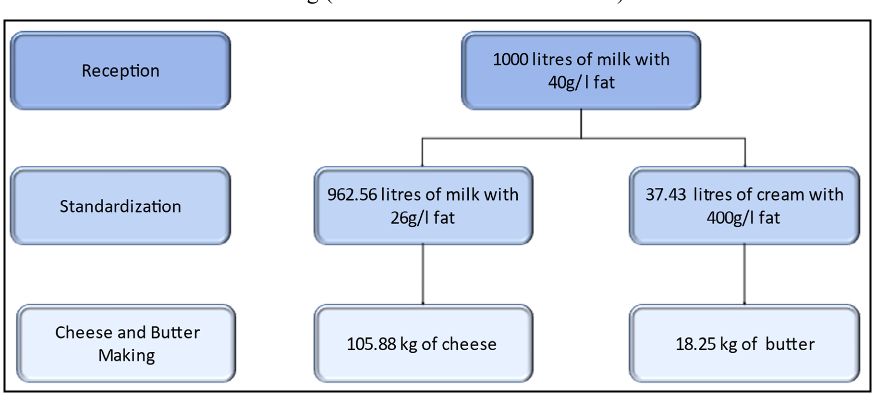
By the above procedure, 962.56 litres of milk comprising 26 g/litre of fat and 37.43 litres of cream with fat content material of 400 g/litre will be produced from 1,000 litres of milk fats content material of 40 g/litre.

In the situation of cheese production, the yield could be about 110 kg of cheese in keeping with 1,000 litres of milk. According to stability due to the standardisation, 962.56 litres of milk with a fats content of 26 g/litre for cheese production will give:

$$\frac{110 \times 962.56}{1000}$$
$$= 105.88 \text{ kg of cheese}$$

For butter production, the yield could be as follows: after standardisation, 37.43 litres of cream with 400 g/litre of fats content material are attained. Thus, the full fats content material could be 15,000 g approximately. The fats content material of butter could be 82%.

Figure 2 Cheese and butter making (see online version for colours)



Therefore, the butter yield could be:

$$\frac{14972}{820}$$
$$= 18.25$$

The procedure of cheese and butter production from 1,000 litres of milk with a fat content of 40 g/litre is shown in Figure 2.

4.1.3 Cost of raw milk

If the usual milk is acquired at 100 litres per day and from the outset of procedures, this milk could be paid Rs R per litre. The value of raw material is consequently 100*R*. The traditional intake is that in 1 litre of milk, the cost of fats content material represents 50% of the rate of the milk (Village Milk Processing, http://fao.org). Therefore, it may be determined that the purchase rate of 1 g of fats content material, if the common rate is 40 g of fats per litre of milk, is:

$$R \times \frac{50}{100} \times \frac{1}{40} = \frac{1}{80} R$$

Also, the butter carries 82% of fats content material and consequently, the cost charge of 1 kg of butter might be primarily based totally on the cost of 820 g of fats content material. Thus, the cost of the required raw milk for 1 kg of butter will be:

$$820 \times 1/80 \times R$$

Now, we are able to decide the cost of raw milk utilised for cheese production. We have already calculated above that 962.56 litres of milk comprising 26 g/litre of fat and 37.43 litres of cream with a fats content material of 400 g/litre will be produced from 1,000 litres of milk fats content material of 40 g/litre. Now, for cheese making, milk with 26 g of fat content material per litre is utilised. The milk is consisting of:

Milk solids (50% of the cost of milk) + fat content material of milk (cost of fats content material at 26 g per litre)

$$R \times 50\% + 26 \times \frac{1}{80} \times R$$

Therefore, the raw milk price of 1 litre of milk for cheese production is:

$$\frac{R}{2} + \frac{26R}{80}$$

As the cheese yield of 1,000 litres of milk for processing is consequently about 110 kg of cheese then the raw milk cost for 1 kg of cheese would be:

$$\frac{\frac{R}{2} + \frac{26R}{80}}{110} \times 1000$$

Table 1 Total cost, sale price and profit of each required product

Product	*Measurement unit*	*Denotation*	*Total cost (Rs)*	*Sale price (Rs)*	*Profit (Rs) notation = D_{Pr}*
Whole milk (4% fat)	Litre	x_1	40	44	4
Toned milk (3% fat)	Litre	x_2	37	42	5
Skimmed milk (2.6% fat)	Litre	x_3	36	39	3
Cheese (from milk 2.6% fat/L)	Kilogram	x_4	270.5	283	12.5
Cream (40% fat)	Litre	x_5	194	202	8
Butter (82% fat)	Kilogram	x_6	370	383	13
Curd (from milk 4% fat/L)	Kilogram	x_7	51.5	59	7.5

Table 2 Different types of costs and their notations

Type of cost	*Value*	*Notation*
Raw milk cost utilisation	647,000	P_{2RMC}
Dairy farm raw milk cost utilisation	54,000	P_{3FRMC}
Collection cost	7,390	P_{4CC}
Packing cost	15,000	P_{5PC}
Commission and transport cost	21,200	P_{6CTC}
Electricity and fuel cost	21,800	P_{7EFC}
Chemical cost	14,050	P_{8ChC}
Distribution cost	13,750	P_{9DC}
Commission to agent	8,250	P_{10CA}
Labour cost	34,700	P_{11LC}

Table 3 Different products with their aspiration levels and notations

Products	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Aspiration level	4,000	2,000	3,000	400	800	500	1,000
Notations	P_{12WM}	P_{13TM}	P_{14SM}	P_{15Ch}	P_{16Cr}	$P_{17B\text{-}}$	P_{18Cu}

At the processing stage, the decision-maker sets the aspiration level of the products according to the available resources as represented in Table 3.

Table 4 Available resources and their notations

Resources	*Quantity*	*Notation*
Raw milk (40 g fat)	22,000 litres	P_{19RM}
Labour time	18,000 minutes	P_{20LT}

The study focused on 12 goals based on the requirements of the dairy producing sector, which are as follows:

Goal 1 maximising profit by 60,500 (notation, 60,500 = P_{1Pr})

Goal 2 reduction of raw milk cost

Goal 3 reduction of dairy farm raw milk cost

Goal 4 reduction of collection cost

Goal 5 reduction of packing cost

Goal 6 reduction of commission and transport cost

Goal 7 reduction of electricity and fuel cost

Goal 8 reduction of chemical cost

Goal 9 reduction of distribution cost

Goal 10 reduction of agents' commission cost

Goal 11 reduction of labour cost

Goal 12 production requirement.

The above data in Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6 is converted into the lexicographic goal programming model and then drawn result with the help of LINGO 18.0 computer software. Goals 1 to 11 are given Priority 1, and production requirement Goal 12 is given Priority 2 based on the decision-maker's choice. The significance of this model is that the satisfaction of goals placed in a higher priority level is stringently chosen to that of goals placed in lower priority levels.

Table 5 Cost utilisation by every product calculated with the help of standardisation of products

Notation	*Cost type*	*Products*						
		x_1	x_2	x_3	x_4	x_5	x_6	x_7
D_{RM}	Required raw milk 40 gm (litres)	1.0	0.874	0.825	7.5	5.5	10.25	1.2
D_{RMC}	Collected raw milk cost	32	0.00	26.4	240	176	328	38.40
D_{FRMC}	Dairy farm raw milk cost	0.00	27	0.00	0.0	0.00	0.00	0.00
D_{CC}	Collection cost	0.5	0.00	0.48	5.00	0.75	1.5	0.6
D_{PC}	Packing cost	1.0	1.0	1.2	3.00	1.5	3	1.5
D_{CTC}	Commission and transport cost	1.5	1.7	1.6	4.0	2.00	4	1.8
D_{EFC}	Electricity and fuel cost	0.8	1.5	2.00	5.00	4.00	6	1.4
D_{ChC}	Chemical cost	0.5	1.00	1.2	3.00	2.5	3.5	1.5
D_{DC}	Distribution cost	1.0	1.0	0.9	2.5	2.00	2.5	1.2
D_{CA}	Commission to agent	0.3	0.7	0.9	1.5	1.0	1.7	0.7
D_{LC}	Labour cost	2.00	2.5	2.7	6.0	4.00	10	3.0
D_{LT}	Labour time (minutes)	1.0	1.25	1.35	3.0	2.75	5.0	1.5

Priority 1

Minimise

$$Z = h_1^- + \sum_{j=2}^{11} \left(h_j^+ \right)$$

subject to

- goal constraints:

Goal 1 maximising profit

$$G_{Pr}(X) + h_1^- - h_1^+ = P_{1Pr}$$

Goal 2 reduction of raw milk cost

$$G_{RMC}(X) + h_2^- - h_2^+ = P_{2RMC}$$

Goal 3 reduction of dairy farm raw milk cost

$$G_{FRMC}(X) + h_3^- - h_3^+ = P_{3FRMC}$$

Goal 4 reduction of collection cost

$$G_{CC}(X) + h_4^- - h_4^+ = P_{4CC}$$

Goal 5 reduction of packing cost

$$G_{PC}(X) + h_5^- - h_5^+ = P_{5PC}$$

Goal 6 reduction of commission and transport cost

$$G_{CTC}(X) + h_6^- - h_6^+ = P_{6CTC}$$

Goal 7 reduction of electricity and fuel cost

$$G_{EFC}(X) + h_7^- - h_7^+ = P_{7EFC}$$

Goal 8 reduction of chemical cost

$$G_{ChC}(X) + h_8^- - h_8^+ = P_{8ChC}$$

Goal 9 reduction of distribution cost

$$G_{DC}(X) + h_9^- - h_9^+ = P_{9DC}$$

Goal 10 reduction of agents' commission cost

$$G_{CA}(X) + h_{10}^- - h_{10}^+ = P_{10CA}$$

Goal 11 reduction of labour cost

$$G_{LC}(X) + h_{11}^- - h_{11}^+ = P_{11LC}$$

Goal 12 production requirement

$$x_1 + h_{12}^- - h_{12}^+ = P_{12WM}$$

$$x_2 + h_{13}^- - h_{13}^+ = P_{13TM}$$

$$x_3 + h_{14}^- - h_{14}^+ = P_{14SM}$$

$$x_4 + h_{15}^- - h_{15}^+ = P_{15Ch}$$

$$x_5 + h_{16}^- - h_{16}^+ = P_{16Cr}$$

$$x_6 + h_{17}^- - h_{17}^+ = P_{17B}$$

$$x_7 + h_{18}^- - h_{18}^+ = P_{18Cu}$$

- hard constraints:

$$G_{RM}(X) \le P_{19RM}$$

$$G_{LT}(X) \le P_{20LT}$$

where

$$G_{Pr}(X) = D_{Pr}(X^T), G_{RMC}(X) = D_{RMC}(X^T), G_{FRMC}(X) = D_{FRMC}(X^{*T}),$$
$$G_{CC}(X) = D_{CC}(X^T), G_{PC}(X) = D_{PC}(X^T), G_{CTC}(X) = D_{CTC}(X^T),$$
$$G_{EFC}(X) = D_{EFC}(X^T), G_{ChC}(X) = D_{ChC}(X^T), G_{DC}(X) = D_{DC}(X^T),$$
$$G_{CA}(X) = D_{CA}(X^T), G_{LC}(X) = D_{LC}(X^T), G_{RM}(X) = D_{RM}(X^T),$$
$$G_{LT}(X) = D_{LT}(X^T)$$

and

$$X = x_l \quad \forall \quad l = 1, 2, 3, \ldots, 7.$$

5 Results

The result of the above-noted problem is drawn with the help of LINGO computer software and the obtained result is shown in Table 6.

Priority 2

Minimise

$$Z = \sum_{j=12}^{18} \left(h_j^- + h_j^+ \right)$$

subject to

- goal constraints:

$$G_{Pr}(X) + h_1^- - h_1^+ = P_{1Pr}$$

$$G_{RMC}(X) + h_2^- - h_2^+ = P_{2RMC}$$

$$G_{FRMC}(X) + h_3^- - h_3^+ = P_{3FRMC}$$

$$G_{CC}(X) + h_4^- - h_4^+ = P_{4CC}$$

$$G_{PC}(X) + h_5^- - h_5^+ = P_{5PC}$$

$$G_{CTC}(X) + h_6^- - h_6^+ = P_{6CTC}$$

$$G_{EFC}(X) + h_7^- - h_7^+ = P_{7EFC}$$

$$G_{ChC}(X) + h_8^- - h_8^+ = P_{8ChC}$$

$$G_{DC}(X) + h_9^- - h_9^+ = P_{9DC}$$

$$G_{CA}(X) + h_{10}^- - h_{10}^+ = P_{10CA}$$

$$G_{LC}(X) + h_{11}^- - h_{11}^+ = P_{11LC}$$

$$x_1 + h_{12}^- - h_{12}^+ = P_{12WM}$$

$$x_2 + h_{13}^- - h_{13}^+ = P_{13TM}$$

$$x_3 + h_{14}^- - h_{14}^+ = P_{14SM}$$

$$x_3 + h_{14}^- - h_{14}^+ = P_{14SM}$$

$$x_5 + h_{16}^- - h_{16}^+ = P_{16Cr}$$

$$x_6 + h_{17}^- - h_{17}^+ = P_{17B}$$

$$x_7 + h_{18}^- - h_{18}^+ = P_{18Cu}$$

- hard constraints:

$$G_{RM}(X) \le P_{19RM}$$

$$G_{LT}(X) \le P_{20LT}$$

and

$$h_1^- = 0, h_2^+ = 0$$

$$h_3^+ = 0, h_4^+ = 0$$

$$h_5^+ = 0, h_6^+ = 0$$

$$h_7^+ = 0, h_8^+ = 0$$

$$h_9^+ = 0, h_{10}^+ = 0$$

$$h_{11}^+ = 0$$

where

$$G_{RMC}(X) = D_{RMC}\left(X^T\right), G_{FRMC}(X) = D_{FRMC}\left(X^{*T}\right),$$

$$G_{CC}(X) = D_{CC}(X^T), G_{PC}(X) = D_{PC}(X^T),$$

$$G_{CTC}(X) = D_{CTC}(X^T), G_{EFC}(X) = D_{EFC}(X^T),$$

$$G_{ChC}(X) = D_{ChC}(X^T), G_{DC}(X) = D_{DC}(X^T),$$

$$G_{CA}(X) = D_{CA}(X^T), G_{LC}(X) = D_{LC}(X^T),$$

$$G_{RM}(X) = D_{RM}(X^T), G_{LT}(X) = D_{LT}(X^T)$$

and

$$X = x_l \quad \forall \quad l = 1, 2, 3, \ldots, 7$$

Again, the result of the above problem is drawn with the help of LINGO computer software and the obtained result is shown in Table 7.

Table 6 Output result of Priority 1

Variables	*Positive deviations*	*Negative deviations*
$x_1 = 3{,}998.138$	$h_1^+ = 0$	$h_1^- = 0$
$x_2 = 2{,}000$	$h_2^+ = 0$	$h_2^- = 0$
$x_3 = 2{,}964.704$	$h_3^+ = 0$	$h_3^- = 0$
$x_4 = 399.8923$	$h_4^+ = 0$	$h_4^- = 0$
$x_5 = 797.4483$	$h_5^+ = 0$	$h_5^- = 0.2902072$
$x_6 = 503.2997$	$h_6^+ = 0$	$h_6^- = 5.474369$
$x_7 = 1{,}025.627$	$h_7^+ = 0$	$h_7^- = 27.15222$
	$h_8^+ = 0$	$h_8^- = 0$
	$h_9^+ = 0$	$h_9^- = 0$
	$h_{10}^+ = 0$	$h_{10}^- = 11.49040$
	$h_{11}^+ = 0$	$h_{11}^- = 0$
	$h_{12}^+ = 0$	$h_{12}^- = 1.861848$
	$h_{13}^+ = 0$	$h_{13}^- = 0$
	$h_{14}^+ = 0$	$h_{14}^- = 35.29639$
	$h_{15}^+ = 0$	$h_{15}^- = 0.1077232$
	$h_{16}^+ = 0$	$h_{16}^- = 2.551740$
	$h_{17}^+ = 3.299675$	$h_{17}^- = 0$
	$h_{18}^+ = 25.62683$	$h_{18}^- = 0$

The output result of Priority 2 of lexicographic goal programming specifies the value of the variables (products) and the value of both deviational variables, whether positive or negative deviational variables, of the desired goals, as shown in Table 7. The results show that the dairy sector will produce 4,000 L of whole milk, 2,000 L of toned milk, 2,966.245 L of skimmed milk, 400 kg of cheese, 797.4684 L of cream, 500 kg of butter and 1,029.536 kg of curd. Table 8 shows the values of the desired goals accomplished in both priorities.

Table 7 Output result of Priority 2

Variables	*Positive deviations*	*Negative deviations*
$x_1 = 4,000$	$h_1^+ = 0$	$h_1^- = 0$
$x_2 = 2,000$	$h_2^+ = 0$	$h_2^- = 802.5316$
$x_3 = 2,966.245$	$h_3^+ = 0$	$h_3^- = 0$
$x_4 = 400$	$h_4^+ = 0$	$h_4^- = 0.3797468$
$x_5 = 797.4684$	$h_5^+ = 0$	$h_5^- = 0$
$x_6 = 500$	$h_6^+ = 0$	$h_6^- = 5.907173$
$x_7 = 1,029.536$	$h_7^+ = 0$	$h_7^- = 36.28692$
	$h_8^+ = 0$	$h_8^- = 2.531646$
	$h_9^+ = 0$	$h_9^- = 0$
	$h_{10}^+ = 0$	$h_{10}^- = 12.33629$
	$h_{11}^+ = 0$	$h_{11}^- = 12.6582$
	$h_{12}^+ = 0$	$h_{12}^- = 0$
	$h_{13}^+ = 0$	$h_{13}^- = 0$
	$h_{14}^+ = 0$	$h_{14}^- = 33.75527$
	$h_{15}^+ = 0$	$h_{15}^- = 0$
	$h_{16}^+ = 0$	$h_{16}^- = 2.531646$
	$h_{17}^+ = 0$	$h_{17}^- = 0$
	$h_{18}^+ = 29.53586$	$h_{18}^- = 0$

6 Discussion

The output result of goals in Priority 1 and Priority 2 is represented in Table 8 (obtained from Table 6 and Table 7).

It is evident from Table 8 that the decision-maker achieved the first 11 goals fully in Priority 1. The cost values of different goals are reduced to some extent in Priority 1 such as packing cost (Goal 5) by 0.0282 Rs, commission and transport cost (Goal 6) by 5.4734 Rs, electricity and fuel cost (Goal 7) by 27.1509 Rs and agents commission cost (Goal 10) by 11.48986. In Priority 2, the decision-maker wants to attain Goal 12 but in the obtained result shown in Table 8 that the decision-maker faces a deviation as objective value 65.82 is achieved and still, the solution is satisfying and all other 11 goals are also satisfied fully in Priority 2. In Priority 2, the production requirement of skimmed milk (x_3) and cream (x_5) products met with an underachievement value of 37.55 litres and 2.5356 litres, and the production requirement of curd product (x_7) met with an overachievement value of 29.536 kilograms. In Priority 2 also, the cost values of a few goals are reduced to some extent such as raw milk cost (Goal 2) by 802.511 Rs, collection cost (Goal 4) by 0.375 Rs, commission and transport cost (Goal 6) by 6.2814 Rs, electricity and fuel cost (Goal 7) by 36.286 Rs, chemical cost (Goal 8) by 2.531 Rs, agents commission cost (Goal 10) by 12.2359 Rs and labour cost (Goal 11) by 12.6569 Rs.

Table 8 Value of each goal achieved in Priority 1 and Priority 2

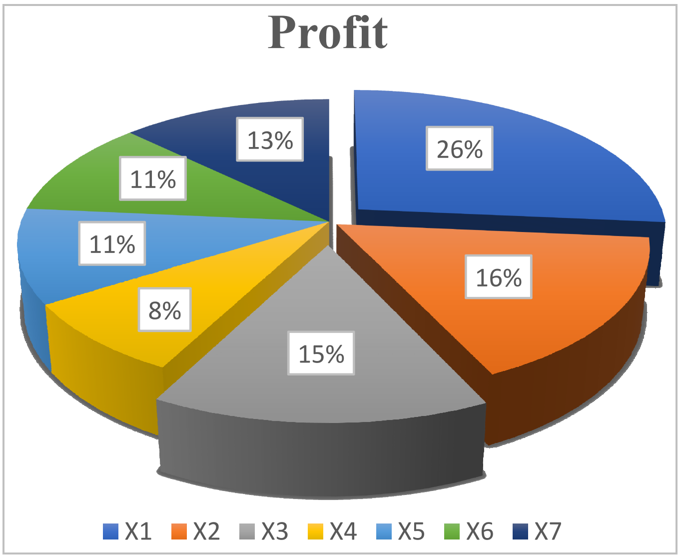
Goals		*Value achieved in Priority 1*	*Value achieved in Priority 2*
Goal 1		60,500	60,500
Goal 2		647,000	646,197.489
Goal 3		54,000	54,000
Goal 4		7,390	7,389.6205
Goal 5		14,999.9718	15,000
Goal 6		21,194.5266	21,194.0936
Goal 7		21,772.8491	21,763.714
Goal 8		14,050	14,047.469
Goal 9		13,750	13,750
Goal 10		8,238.51014	8,237.7641
Goal 11		34,700	34,687.3431
Goal 12	x_1	3,998.138	4,000
	x_2	2,000	2,000
	x_3	2,964.704	2,966.245
	x_4	399.8923	400
	x_5	797.4483	797.4684
	x_6	503.2997	500
	x_7	1,025.627	1,029.536

By the application of the linear programming model, only two products are produced, namely 1,900 litres of whole milk and 8733 kgs of curd. Comparing the results to the linear programming models it can be found that the proposed model (lexicographic goal programming) helps the decision-maker to produce all of the required products in order to meet the demands of the customers and to compete with other dairy sectors in its area. In addition, some other specified objectives are not met such as the optimisation of cost goals to some extent, which is not an acceptable solution for the decision-makers. As a result, the lexicographic goal programming technique outperforms the linear programming technique.

Overall, the lexicographic goal programming technique determines the optimum solution and the profit maximisation goal is achieved fully as profitability is an important factor of production sectors because they are basically established to gain profit. As, a result the proposed model indicates that the dairy production sector has to prepare

4,000 litres of whole milk, 2,000 litres of toned milk, 2,966 litres of skimmed milk, 400 kgs of cheese, 797 litres of cream, 500 kgs of butter and 1,030 kgs of curd to achieve desired value for the other intended goals. Thus, the average profit share of each product in both priorities to the total profit of 60,500 Rs is shown in Figure 3.

Figure 3 The profit share of products (see online version for colours)



To summarise, the current findings show that the prevailing approach is an efficacious and efficient approach for decision makers, acting as a decision support tool to cope with this type of dairy production planning problem and to adjust the production system in different scenarios with the aim of achieving several conflicting objectives simultaneously.

7 Conclusions

The main objective of this study was to develop a mathematical technique to encounter real-life problems and the obtained solution set can be implemented as a decision-support instrument for production planning in the milk manufacturing industry. The lexicographic goal programming model is formulated as it involves several priority levels as compared to general goal programming models and shows its applicability by using industrial cases and drawn solutions using the standard LINGO 18.0 software package. The proposed model is significant in that it is intended to act as a decision-making tool for decision-makers in the dairy production sector, particularly when dealing with production planning problems, as there has been little use of multi-objective mathematical models to cope with these types of scenarios in dairy sectors.

As dairy sectors face a lot of problems during production planning and there is less implementation of multi-objective mathematical models to achieve different objectives simultaneously. As a result, the present study with the lexicographic goal programming model helps the decision maker to achieve several objectives simultaneously and delivers the optimum solution in the dairy production sector. Also, in this study, the mathematical technique describing the uncertain lifetime decides optimum schedules yielding maximum production and reducing the cost of the resources as an indicator of maximum benefits in the production of dairy products. Thus, the present research work provides a potential model for industrialists to overcome different problems that arise in the production process.

The study can be expanded in several ways, which can be recommended as future research fields. First, sensitivity analysis can be performed on various parameters such as goal constraint parameters, goal weighting and change in priorities to investigate their impact on lexicographic goal programming and how far the optimal solution and target goal values fluctuate under the given set of circumstances. Secondly, when there is uncertainty in the goal parameters, fuzzy sense can be applied. Finally, to meet this type of production planning challenge, it might be broadened to neutrosophic-type characteristics.

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