Progress in Nonlinear Dynamics and Chaos
Vol. 9, No. 1 & 2, 2021, 37-44
ISSN: 2321 – 9238 *(online)*
Published on 10 September 2021
www.researchmathsci.org
DOI: http://dx.doi.org/10.22457/pindac.v9n1a09004

Progress in Nonlinear Dynamics and Chaos

A Distribution Model Related to the Dairy Industry of Sri Lanka

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Received 2 August 2021; accepted 4 September 2021

Abstract. The open economic policy in 1977 resulted in an increase of the consumption of dairy products in Sri Lanka. Such an increase of the consumption of dairy products has led to enormous potential for country's economic development. Nevertheless, the dairy farming sector in Sri Lanka encounters distribution challenges with mapping demand and supply of dairy products. While distribution, raw milk does get spoiled which, is caused to waste a considerable amount.

Sri Lanka Milk Foods (SLMF) is a group of companies that provides dairy products to the Dairy Market in Sri Lanka. In order to find a feasible path that satisfies constraints identified by the SLM, a web-enabled Enterprise Resource Planning (ERP) is designed to minimize the total costs of milk processing and transportation. It is conjectured that the integer programming model developed to optimize product allocation and distribution would help to minimize the respective costs fostering the business's growth.

Keywords: Sri Lanka Milk Foods (SLMF); Enterprise Resource Planning; Integer Programming; LINGO

AMS Mathematics Subject Classification (2010): 90C10, 90C05, 90C90

1. Introduction

Many companies look for a long-term plan to remain undaunted in their fields of business. The situation is same in the dairy industry. The dairy industry follows its own business processes to reach outputs. The dairy industry processes raw milk to produce different types of milk products. However, raw milk does get spoiled easily so that the dairy industry needs to pay much attention to better management of distribution and transport planning.

In the modern world, computer-based integer programming algorithms are used for solving problems [6]. Instead of destination and source constraints, Hitchcock proposed a conventional transportation model [3]. Saranya introduced a model to detect the best availability shortest paths for any complex routing [9]. The geometric programming is an approach to minimize fuzzy multi objective transportation problem. Islama and Roy [4], Gupta et al. [2] proposed methods to solve this fuzzy transportation problem. Sakawa et al. [8] introduced a model to solve the real production and transportation problem of multiproduct to minimize the costs of transportation and production. This formulation is based on fuzzy programming that is used to solve the problem in a fuzzy environment.

Kumar [5] built a software-based model for solving fuzzy solid assignment problem (IFSAP) and its crisp solid assignment. Voskoglou developed a method for assessing the human skills of a group of individuals using fuzzy assessment [7]. Using mixed-integer programming, Zhao and Stecke [10] provided an optimal production schedule to minimize the total shipping costs for a single product problem. Similarly, Cunha and Muturelli [1] introduced a mixed-integer programming model for production and distribution to minimize total costs using a spreadsheet optimization model.

In this paper, we provide solutions to major problems that arise in the dairy industry in Sri Lanka based on SLMF where we deal with a multiple product problem to minimize the total costs of processing and distribution of milk products on the basis of customers' demand, spoilage times in different types of milk, distances between bottling plants and vendors so on. This research was based on the following assumptions:

1. The supply collect from outlets is sufficient to meet the customers' demand.
2. All the products are manufactured using raw milk collected from the same day and such products are delivered to the customers on the very same day.

The main part of this project was to solve the problem with the aid of a web-enabled database using Php, MySQL, and Lingo programs. An integer program was formulated using Lingo to update the database and display output through the web. Accordingly, the database was updated every day regarding the vendors, bottling plants for sale, and collecting plant inputs via the website.

2. The production-transportation problem

The SLMF, a leading manufacturer of dairy products uses five bottling plants which are located in different geographical locations for operation. At present, the company has a wide range of supplies with four collecting outlets in different cities to produce three types of products, namely, yogurt cups, milk bottles and milk powder packets which are shipped to five customer locations. On each day, customers place their orders at the sales offices. Such orders will then be forwarded to the main office in order to produce the needs on the very same day. While retaining, relevant information, the main office will also transfer them to the bottling plants and collecting outlets.

As soon as the products are manufactured, they are shipped to the customers from the bottling plants depending on the location of bottling plants and customers. Customers usually specify their preferred types of products whether yogurt cups, milk bottles or milk powder packets. The company receives five different customers' orders each day to produce and ship out it on the same day. Whenever, a new order is placed, it is entered into the company's Enterprise Resource Planning System and assigned to the bottling plants and collecting outlets through web. The company products have different requirements i.e., in each type of raw milk has different uses and can also be used 1 l of milk to produce the specific number of units of products (Table 3.1). Milk processing which is done by the collecting outlets is the intermediate step of the production chain to reach the production requirements. Therefore, the primary objective of collecting outlets is processing collected raw milk into three types, namely, A, B, and C. Each type has a different expiration time which cannot be exceeded by the distribution of raw milk from collecting outlets to the bottling plants (Table 3.2).

Table 3.1: Number of units from 1l of milk

	Yoghurt	Milk bottle	Milk powder
Type A	10	03	-
Type B	-	05	02
Type C	08	-	01

Table 3.2: Expiration time

Type	Expiration time (in min.)
A	330
B	300
C	270

The company's Enterprise Resource Planning system which is linked to the internet will be accessed on each day by the vendors, a member of each collecting outlet, and a member of each bottling plant by entering user IDs and passwords that are given by the company's IT unit. Subsequently, a form will be displayed on the ERP system where the vendors are expected to fill the demand of yoghurt cups, milk bottles and milk powder packets. Similarly, all the inputs of the temperature of collecting outlets and quantity collected from buffalo milk, cow milk and milk cream will also be entered in the form by the collecting outlet. A member of the bottling plant needs to fill the form only for temperature. The company has a machinery constraint to set up machines in each bottling plant.

The distance between the vendor and the bottling plant should be less than 250km. Each bottling plant should be able to satisfy at least 10% of the total demand of vendor for each product. As revealed by company's old data, Costs of delivering a liter of type A milk are 0.4 Rupee, type B milk is 0.5 Rupee, and type C milk is 0.3 Rupee; processing cost of 1L of Grade A milk for Yogurt is 0.7 rupee Grade C is 0.75 rupee; processing cost of 1L of Grade A milk for Milk bottle is 0.5 rupee Grade B is 0.6 rupee; processing cost of 1L of Grade B milk for Milk powder is 0.8 rupee Grade C is 0.85 rupee; delivery cost per kilometer from the bottling plant to the vendor is 1 Rupee.

3. The solution approaches

In order to minimize both costs of processing raw milk and transportation, the SLMF wanted to allocate customer orders to their bottling plants. Owing to the complexity involved with the production process and the distribution due to a large number of daily orders, mapping supply and demand among the collecting outlets, bottling plants and vendors must be done considering factors such as transportation costs, expiration time of each type of raw milk, distances between collecting outlets to bottling plants as well as bottling plants to the vendors.

To help solve this problem, we developed an optimization model to be used by the central management for planning their daily orders and allocations. First of all, it needed to get a proper knowledge of distances between collecting outlets and bottling plants, transportation time, distances between bottling plants and vendors. Therefore, as initial step, we have constructed distance and time (in min.) tables. The rows indicate collecting outlets while columns indicate bottling plants (Table 4.1 & 4.2). The rows and columns indicate bottling plants and vendors respectively (Table 4.3).

Table 4.1: Distance of collecting outlets and bottling plants

	Colombo	**Gampaha**	**Matara**	**Polonnaruwa**	**Kandy**
Kantale	218	194	354	69	142
Anuradhapura	209	179	338	102	137
Hambanthota	247	253	102	270	251
Nuwara-Eliya	158	141	226	183	72

Table 4.2: Transportation time (in min.) of collecting outlet and bottling plants

	Colombo	**Gampaha**	**Matara**	**Polonnaruwa**	**Kandy**
Kantale	255	198	305	70	151
Anuradhapura	288	201	308	83	161
Hambanthota	166	168	77	278	248
Nuwara-Eliya	176	156	210	213	78

Table 4.3: Distance of bottling plants and vendors

	Kandana	**Mathugama**	**Galle**	**Mahiyanganaya**	**Kaduwela**
Colombo	15	71	131	195	16
Gampaha	18	78	138	165	23
Matara	166	96	45	244	144
Polonnaruwa	214	263	323	92	208
Kandy	114	162	222	77	108

The following variables are defined to formulate the problem.

- **Xijk**=number of a liter of type ‘i^{th}’ milk send from ‘j^{th}’ collecting outlet to ‘k^{th}’ bottling plant.
- **Yijk**=If it is possible to send ‘i^{th}’ type of milk from ‘j^{th}’ collecting outlet to ‘k^{th}’ bottling plant.
- **Zijk**=number of ‘i^{th}’ products deliver from ‘j^{th}’ bottling plant to ‘k^{th}’ vendor.
- **Wij**=If it is possible to deliver products from ‘i^{th}’ bottling plant to ‘j^{th}’ vendor.
- **YPij**=Yogurt production from ‘i^{th}’ grade of milk of ‘j^{th}’ bottling plant.
- **MBPij**=Milk bottle production from ‘i^{th}’ grade of milk of ‘j^{th}’ bottling plant.
- **MPPij**=. Milk powder production from ‘i^{th}’ grade of milk of ‘j^{th}’ bottling plant.

From these four different classes of decision variables, **YPij ,MBPij ,MPPij,Xijk** and **Zijk** are classes of integer variables while **Yijk** and **Wij** are classes of identity variables that take 1 if satisfy a condition 0 otherwise.
To probe deeper into the issue, it needs to consider the expiration time of each type of milk. Thus, the following assumptions are made:

a) Temperature of each bottling plant and collecting outlet remains same throughout the day.
b) There are no factors other than the temperature which affects the expiration time of raw milk.
c) Expiration time of each type of raw milk has a linear relation with temperature.

We introducedifferent linear factors for each type of milk for simplicity (Table 4.4).

Table 4.4: Linear factors of each type of raw milk

Type	Linear factor
A	0.007
B	0.008
C	0.009

The next step is to calculate the modified expiration time using the equation below which is used hereafter for all calculations pertaining to the all-possible distribution paths from each collecting outlet to the bottling plant for all types of raw milk.

Modified expiry time (Tijk)=Expiry time in room temperature (Ti) (1+linear factor×(temperature ofcollecting outlet-temperature of bottling plant))

Now we calculate the value of the difference between modified expiration time of each type of raw milk from each collecting outlet to bottling plant and transportation time of each collecting outlet to bottling plant using transpiration time.

Aijk =Tijk-tij

Tijk= Modified expiration time of i^{th} type milk sent from j^{th} collecting outlet to k^{th} bottling plant.
tij=Transportation time between i^{th} collecting outlet and the j^{th} bottling plant.

Since **Aijk**>=0 that is 'modified expiration time >= transportation time', therefore distribution of i^{th} type milk from j^{th} collecting outlet to k^{th} bottling plant is possible.

If **Aijk**<0 that is 'modified expiration time<=transportation time' then it is impossible to distribute such type of milk from that collecting outlet to the bottling plant.

In the next step, similar to the previous one we calculated the difference of distance between the bottling plant and the vendor with a '250km' distance limit.

Bij=Dij-250

Dij=Distance between 'i^{th}' bottling outlet to 'j^{th}' vendor.

Since **Bij**>=0 that is **Dij**>=250, therefore, it is possible to distribute products from the ‘i^{th}’ bottling plant to the ‘j^{th}’ vendor. Otherwise, it is impossible to distribute products from such bottling plant to the vendor.
To run the lingo program avoiding infeasibilities we introduced two sets of inequalities that build the connection with **Xijk** and **Yijk, Zijk** and **Wij**. Following the inequalities introduced, **Xijk** cannot exceed the supply of j th collecting outlet; **Zijk** cannot exceed the demand of ‘i^{th}’ product for ‘k^{th}’ vendor.

Xijk<=Sij×Yijk
Sj=supply of ‘j^{th}’ collecting outlet

Zijk<=Dk×Wij
Dk=demand of ‘k^{th}’ vendor

The formulated integer program is given below:

Parameters: -

djk =Distance of j^{th} collecting outlet and k^{th} bottling plant
Dij=Distance of i^{th} bottling plant and j^{th} vendor
Sij=Supply of i^{th} type of milk from j^{th} collecting outlet
Yk=Yogurt demand of k^{th} vendor
MBk=Milk bottle demand of k^{th} vendor
MPk=Milk powder demand of k^{th} vendor

Optimization model: -

Min Z=0.4∑j∑k djk×Y1jk+0.5∑j∑k djk×Y2jk+0.3∑j∑k djk×Y3jk+∑j∑k Dij×Wij+0.7∑jYP1j+0.75∑Jyp3j+0.5∑jMBP1j+0.6∑jMBP2j+0.8∑jMPP2j+0.85 ∑jMPP3j

Subject to:-

∑k Xijk<=Sij ***(supply of i^{th}type of raw milk from j^{th} collecting outlet)***
∑kXijk>=100 ***(At least 100L of raw milk send from j^{th} collecting outlet)***
Tijk×Yijk>=0 **(*Expiry time*)**
10 YP1j+8 YP3j= ∑k Z1jk ***(Yogurt production from j^{th} bottling plant)***
3 MBP1j+5 MBP2j= ∑k Z2jk (***Milk bottle production from j^{th} bottling plant)***
2 MPP2j+ MPP3j= ∑k Z3jk ***(Milk powder production from j^{th} bottling plant)***
∑j Z1jk=Yk ***(Yogurt demand of k^{th} vendor)***
∑j Z2jk=MBk ***(Milk bottle demand of k^{th} vendor)***
∑j Z3jk=MPk ***(Milk powder demand of k^{th} vendor)***
YP1j+YP3j>=100 ***(Machinery constraints for yogurt production in j^{th} bottling plant)***
MBP1j+MBP2j>=100 ***(Machinery constraints for bottled milk production in j^{th} bottling plant)***
MPP2j+MPP3j>=150 ***(Machinery constraints for milk powder production***

in j^{th} bottling plant)

$YP1j+MBP1j=\sum_i X1ij$ ***(Received type "1" raw milk of j^{th} bottling plant)***

$MPP2j+MBP2j=\sum_i X2ij$ ***(Received type "2" raw milk of j^{th} bottling plant)***

$YP3j+MBP3j=\sum_i X3ij$ ***(Received type "3" raw milk of j^{th} bottling plant)***

$\sum_k Z1jk>=0.1\sum_k Y_k$ ***(At least 10% of Yogurt demand is satisfied by j^{th} bottling plant)***

$\sum_k Z2jk>=0.1\sum_k MB_k$ ***(At least 10% of Milk bottle demand is satisfied by j^{th} bottling plant)***

$\sum_k Z3jk>=0.1\sum_k MP_k$ ***(At least 10% of Milk powder demand is satisfied by j^{th} bottling plant)***

$B_{ij}\times W_{ij}<=0$ ***(Distance between bottling plant and vendor is less than or equal to 250km)***

$Z_{1jk}<=Y_k\times W_{jk}$ ***(Production capacity)***

$Z_{2jk}<=MB_k\times W_{jk}$ ***(Production capacity)***

$Z_{3jk}<=MP_k\times W_{jk}$ ***(Production capacity)***

$X_{ijk}<=S_{ij}\times Y_{ijk}$ ***(Milk Processing capacity)***

4. Development of ERP system

We developed ERP system using Php, javascript, and MySQL to obtain inputs of vendor demand, supply, temperature of each collecting outlet and bottling plant and to display output on the board via web. The design of the system was done by a bootstrap template.

Acknowledgments. The author would like to express sincere gratitude to C. J. Jayawardene Dr. Buddhini Wijesuriya and Miss Sasandi Pahanmi for assisting with modeling and implementation of this project.
Also, the author would like to thank the referees who provided useful and detailed comments in improving the paper.

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