ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 9(45), DOI: 10.17485/ijst/2016/v9i45/105954, December 2016*

Modeling Vegetable Food Supply Chain by the Prediction of Yield and Demand for a City to Reduce Food Waste

S. Nagabhushana, N. S. Narahari and C. K. Nagendra Guptha

Department of Industrial Engineering and Management, R V College of Engineering, Bengaluru – 560 059, Karnataka, India; bushan.dbz@gmail.com, nagendragupta@rvce.edu.in

Abstract

Tons of vegetables go to waste as they are produced in excess than the current demand and go to waste in storage units without any customer to buy them. The objective of the study is to develop a model that helps in effective distribution of vegetable yield demand. Prediction model was developed using regression analysis to find out the future yield so that the farmer can plan the distribution of his produce. Second phase of the study was aimed at reducing transportation using cost integer programming from distributors to retailers while meeting the demand at the same time. The developed model can predict the future yield value which will be closer to the actual yield value. Future demand can also be determined which will be closer to the actual demand. Based on the yield generated and demand comparison, decision can be incorporated in the distribution of vegetables by the farmer to different regions. If the demand is more than yield, tapping of other sources is done. If the demand is lesser, the part of the yield can be sent to other towns and cities where demand has not been met. Food waste problem can be tackled at the source itself by using this model. Wastage can be reduced considerably which is one of the final benefits that will contribute to the societal welfare and development. The integer programming model done for optimizing the cost of distribution provides a feasible solution to the distributors and retailers and satisfying the demand at the same time. Thus, total cost can be minimized without affecting the efficiency of distribution. Distributors and retailers can optimize their distribution effectively while minimizing the transportation cost as much as possible without affecting the demand.

Keywords: Food Supply Chain, Integer Programming, Linear Regression, Winter's Demand Forecast Model, Yield Prediction Model

1. Introduction

One of the major crises the world is facing today is food wastage. Starting from production to reaching the end customers, each stage of supply chain is associated with food wastage. Due to this, many Food Supply Chains (FSC) are being studied to monitor and control waste. For a certain region with a certain demand, supply may be in excess sometimes which leads to wastage. Supply may also be limited sometimes. When the supply is in excess, we need to channel it to another region where current supply might be less than demand. In order to do this, it is very much necessary that the farmers have a definite idea about the quantity that they are going to produce in the future and also the demand of the different regions to which they are distributing their yield. The next level of FSC involves wholesalers that form the middlemen and the retailers. Transfer of vegetables from one stage to another for a particular region also requires analysis so that food waste during transportation is reduced and at the same

**Author for correspondence*

time, cost of transportation is also optimized to a certain extent. Different factors like type of transportation, quantity to be distributed, frequency of transportation and cost of transportation are to be considered.

2. Food Supply Chain Optimization Techniques

Total study of FSC of a region involves the study of the different sources of vegetables which distribute them to different places and the study of distribution inside the region so as to get a clear view of the complete FSC process which helps in developing a model that aids in effective distribution of vegetables and reduces wastage at the same time.

Many of the factors like temperature, cost, and distance were considered to make a mathematical model by setting up constraints and in turn were converted to a network model with related nodes and distances[1]. They gave a methodology to plan and implement cold chain logistics for distribution of agricultural products. Thus, cold chain logistics route was optimized based on the above factors for an area. Quality degradation rate is different for different food items at different temperature. Based on this, a model was developed which takes into account the above functions along with cost and distance constraints to effectively design an FSC. Survey based research on many perishable food items manufacturing and distribution companies based on their supply chain tiers, distance, cost of supply and frequency and cost of supply chain for different stages is also done[2,3]. Based on this survey, they came to a conclusion where the supply chain tiers must be short and frequent to tackle the current FSC disadvantages rather than long and infrequent supply chains. They have also given a mathematical model for distribution stage of FSC as a function of quality degradation of food with respect to time and temperature. Vehicle routing problem with time windows for a food distribution company for delivering perishable food items was done by developing Software based Optimization of delivery routes was made along with other factors like time, distance and cost[4]. A mathematical programming model was developed with algorithms to accommodate each of the above function. All these focused on most effective and quicker delivery of perishable products for a particular region. Papers focus generally on network planning, design and a final transportation implementation based on the food quality and safety issues[9].

Review papers on food quality management, safety and transportation issues[5] are also done. Finally, the models were reviewed for their advantages and future challenges it holds. Due to extensive pilferage and wastage of perishable food items, tracking of food items starting from their produce was studied. Food distribution involving farmers, retailers, wholesalers and customers was studied with the help of Global Positioning System (GPS) which resulted in optimizing the route of transportation using network analysis[6,8]. Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method for modelling the FSC of a protein manufacturing food industry was done. The study is mainly used for selecting the different suppliers from a vast list of suppliers considering transportation cost, distance, food quality degradation and procurement costs. All these constraints were used in order to develop a model for selecting optimum suppliers. Implementation of Lean manufacturing ideas towards distribution sector for perishable food items is an upcoming trend[7].

Lean transportation is the expansion of the current lean manufacturing idea which encompasses the supply chain aspect of any industry. Just in time, waste reduction, delivery frequencies and pull system were incorporated for FSCs. The main reason being pollution and increased Green House Gases that contributes to Global warming. Many environmental sustainability plans were suggested that help in preserving the quality of fruits in all the stages of FSC.

3. Problem Identification and Research

Information technology has reached farmers so that they can get an idea about the weather pattern, rainfall prediction and current market rate for their produce. GPS tracking system also enables to monitor their fields online along with information about ground water, soil properties etc. Many of the Government schemes like e-krishi, e-agriculture seva help farmers of India to obtain this information at a reasonable cost. Bharti Airtel and Vodafone are also involved in providing these services to farmers. This information can help farmers predict their future yield so that, they can distribute it effectively to the nearby regions which correlates to the demand of vegetables of those regions. Since food wastage occurs mainly due to improper distribution, it can be avoided to a certain extent. Distribution systems of wholesalers and retailers also need to be optimized so that food wastes and transportation cost can be reduced sufficiently while meeting the required demand of each outlet retail stores.

Bangalore also has a large share of vegetable wastage in all the FSC stages starting from supplier i.e., farmers to the consumers. Market areas of Bengaluru contribute 2 to 3 tons of vegetable wastes as there is no customer to buy them. This is because the farmers bring excess produce to the market which finally ends up as waste. There is no system present to monitor these activities. At the same time, many other rural regions suffer from lack of food availability. This is due to improper distribution of vegetables and lack of demand – supply coordination. Once a certain amount of produce is sent to Bengaluru, the next step is to avoid wastage in transportation and distribution of vegetables in between the different stages of food supply chain. It may be from farmer to retailer, wholesaler to consumer, wholesaler to retailer or retailer to consumer. These are the different types of possibilities of vegetable distribution where wastage needs to be reduced. This means, effective distribution has to take place before the food quality reduces below the consumption level.

4. Research Methodology

The study involves the wholesalers and retailers of vegetable trading business. Agricultural Pricing Market Committee (APMC), Bengaluru acts as a mediator between farmers and the market. It decides the farmer's and the wholesale price of the agricultural produce based on the demand, quality and quantity of the vegetables produced. Another important function of APMC is to determine sources for different agricultural products and distributing them to the different market areas of different cities and towns in right quantities. APMC controls all these functions to eliminate the menace of the farmers and the middlemen.

4.1 Study of Wholesalers

The purchasing system of wholesalers from the farmers who bring their produce to the market was observed. Farmer decides on a price for each vegetable based on their quantity of availability. More the quantity, lesser will be the price and lesser the quantity, more the price. It also depends on the quality of the vegetables. Lesser quality vegetables fetch lesser prices in the market. Higher quality vegetables grown organically fetch more prices. Wholesalers decide on a price to sell to the retailers and customers. Prices will be fluctuating based on the quality of the vegetables. As time passes, degradation of quality occurs and simultaneously, the price decreases. There is no cold storage facility for storage in the wholesale market. Thus, wastage of vegetables occurs heavily in this section of FSC. If the wholesalers purchase the vegetables more than the required demand, tonnes of vegetables go to waste.

4.2 Study of Retailers

Retail sector involves Retail shops and hand carts who buy vegetables from the wholesalers and sell them to consumers at a higher retail price. There are organisations like MORE, Reliance Fresh, Big bazaar and Hopcoms who purchase the vegetables directly from farmers eliminating the middle men. They have their own places of collection of vegetables from farmers at different regions. They distribute the vegetables to warehouses located near the customers. Distribution to different retail outlets is done from these warehouses. Warehouses and outlets are well equipped with cold storages for quality preservation of vegetables. Apart from this, many online marketing organisations like Big Basket, Ask Grocery etc., also buy the vegetables directly from the farmer and distribute them from different places of collection to warehouses. On placing the order online, distribution to the customer is directly done from their nearest warehouse to the customer.

4.3 Development of Yield Prediction Model

Based on the previous data collected, a conceptual model is to be prepared for the forecasting of future vegetable yield. As the farmer does not know his future produce and demand to be met, his distribution of vegetables lacks efficiency where supply will be excess than demand in some regions which leads to wastage. Consequently, some regions do not get adequate supply which will be less than the demand. Forecasting yield is done with respect to the rainfall forecast for that region. As the produce mainly depends on rainfall, weather forecasting is compared with the yield to be produced. This involves creating a database which relates the rainfall with the yield for the previous years. Adequate rainfall gives maximum yield whereas less rainfall or excess rainfall minimizes the quantity and quality of the yield. Future yield is calculated for next 2 to 3 months which is the average time for vegetables to grow. The analysis of the data collected involves the relating the yield data to rainfall data. For this, Regression model is to be used where the yield and rainfall data are made into a scatter plot. Then, fitting the line is done using the method of least squares. After line fitting, the corresponding regression equation is obtained so that we can determine the yield value at any given rainfall value for different vegetables.

5. Data Collection and Analysis

The study involves modelling an effective distribution system among retailers in order to optimize the cost and meeting the demand at the same time. Integer programming is used for this purpose. Study of distribution to retailers was done for a grocery retail store. Based on the demand of different outlets, they procure the vegetables at the Manti and distribute them to various retail outlets. Some of the horticultural products like fruits need processing and ripening. These are sent to the processing centres and then to the retail outlets.

5.1 Cost Optimized Distribution among Retailers

The whole system is integrated by SAP software which generates the order quantity and sends it to the distribution centre at the re order point. Distribution takes place using trucks of different load capacities and is on contractual basis. The process of procuring is as follows:

1. The store manager and the Supply Chain Management (SCM) manager determine and predict the demand based on previous sales data.
2. Order is sent to the DC when the inventory level comes to the re order point.
3. SCM manager processes the order, procures the vegetables accordingly and it is received at the DC
4. The vegetables are processed and sorted out. Rotten ones are taken out. Good vegetables are then placed in crates which are germ resistant and specially designed to store vegetables.
5. They are kept in cold storage until the point of delivery.
6. They are delivered to the outlets according to the requirements of each store.
7. No. of crates and weight of each crate is recorded at collection point, DC and the store to check pilferage and accurate tracking of the vegetable quantity.

In order to determine the total cost of the vegetables procured, various costs involved in the working process is split up as follows:

1. Purchase cost (P_c)– cost of vegetables purchased from farmers
2. Crating charge (C_c)– labour cost for crating the vegetables (20 kg capacity - Rs. 3 per crate)
3. Loading cost (L_c)– labour cost for loading the crates on to the truck (Rs. 0.075 per kg)
4. Agricultural Produce Market Committee (APMC) cost (A_c) – charge given to APMC at Mandi (0.8 % of the total purchase cost)
5. Vendor charge (V_c) – cost of vegetable vendors (6% of total purchase cost)
6. Refrigeration cost (R_c) – cost of using the cold storage (Rs. 0.6 per kg)

7. Labour cost (Lb_c)– amount given to the retail store workers (Rs. 0.8 per kg)
8. Transportation cost (T_c) – cost for transporting vegetables from Collection Center (CC) to Distribution Center (DC) and from DC to Outlet stores. (Rs. 200 for 3 km and Rs. 15 for additional km)

All the costs are considered and the total cost is calculated using Integer Programming so that it is minimised and at the same time, demands are met. The parameters are as follows:

i is the index for customers ($i \in I$)

j is the index for Distribution Centre DC ($j \in J$)

k is the index for Collection Centre CC ($k \in K$)

q_{ji} is the quantity of vegetables per truck shipped from DC to Retail store

q_{kj} is the quantity of vegetables per truck shipped from CC to DC

y_{ji} = 1 if DC serves Retail store, 0 otherwise

y_{kj} = 1 if CC serves DC, 0 otherwise

d_i = demand of the vegetable

w_j = distribution capacity of DC

c_{ji} = unit transportation cost from DC to Store

c_{kj} = unit transportation cost from CC to DC

n = number of trucks

Tl_c = Total cost = $P_C + C_c + L_c + A_c + V_c + R_c + Lb_c$

Objective function:

Minimize $f = \sum c_{ji} q_{ji} + \sum c_{kj} q_{kj}$
where f is the total cost
such that,

$$\sum y_{ji} = 1 \quad , \forall\ I \qquad (1)$$

$$\sum y_{kj} = 1 \quad , \forall\ j \qquad (2)$$

$$\sum d_i y_{ji} \le w_j \quad , \forall\ j \qquad (3)$$

$$nq_{ji} = d_i y_{ji} \quad , \forall\ i, \qquad (4)$$

$$nq_{kj} \le w_j y_{kj} \quad , \forall\ j, k \qquad (5)$$

$$y_{ji} = \{0,1\} \quad , \forall\ i, j \qquad (6)$$

$$y_{kj} = \{0,1\} \quad , \forall\ j, k \qquad (7)$$

$$q_{ji} \ge 0 \quad , \forall\ i, j \qquad (8)$$
$$q_{kj} \ge 0 \quad , \forall\ k, j \qquad (9)$$

In the above model,

Constraint (1) shows that the retail store is approached by only one DC,

Constraint (2) shows that the DC is approached by one CC,

Constraint (3) shows that the total demand at the retail store should be less than or equal to the capacity of the DC,

Constraint (4) shows that the total quantity of vegetables shipped in trucks from DC should be equal to the demand of the Retail outlet,

Constraint (5) shows that the total quantity of vegetables shipped in trucks from CC to DC should be less than or equal to the capacity of the DC,

Constraints (6) and (7) guarantee that the decision variables are binary

Constraints (8), (9) and (10) guarantee that the decision variables should be an integer and always greater than or equal to zero.

The values for the above decision variables were substituted by studying delivery of carrots on 3rd May 2016. The carrots were collected at the CC in the market and then sent DC at Koramangala, Bengaluru. After crating, they were sent to the Retail store at Srinivasnagar store, Bengaluru. The quantity ordered was based on the demand of the previous month. From this study, the following values were obtained for all the constraints of the model.

q_{ji} = 340 kgs, q_{kj} = 2100 kgs,

y_{ji} = 1 if DC serves Retail store, 0 otherwise

y_{kj} = 1 if CC serves DC, 0 otherwise

d_i = 340 kgs

w_j = 2500 kgs for each vegetable

c_{ji} = unit transportation cost from DC to Store for 13.2 km, the total cost is Rs. 338

c_{kj} = unit transportation cost from CC to DC for 12.7 km, the total cost is Rs. 390.5

Substituting these values in the above model, the solution for minimum cost was obtained from Toolkit for Oracle (TORA) software. The input values are shown in the Figure 1. The output result is shown in the Figure 2.

The optimized distribution cost obtained is Rs. 40778

For this various fixed costs are added to find the total cost. They are:

1. Purchase cost (P_c): Rs. 24 per kg
   Rs. 50400 for 2100 kgs
2. Crating charge (C_c): Rs. 315 for 105 crates
3. Loading cost (L_c): Rs. 157 for loading 105 crates
4. APMC cost (A_c): Rs. 40.32
5. Vendor charge (V_c): Rs. 3024
6. Refrigeration cost (R_c): Rs. 1260
7. Labour cost (Lb_c): Rs. 1680

Total cost is he sum of all the above costs added to the optimized distribution cost – Rs. 97,654.82. This study can be done to find out the optimum cost for any vegetable distribution according to the demand of the consumers at the Retail stores. Thus the entire network

INPUT GRID - INTEGER PROGRAMMING

	x1	x2	Enter <, >, or =	R.H.S.
Var. Name	veg 1	veg 2		
Minimize	4658.00	36120.00		
Constr 1	340.00	0.00	<=	2100.00
Constr 2	340.00	0.00	<=	2500.00
Constr 3	0.00	2100.00	<=	2500.00
Constr 4	340.00	0.00	>=	0.00
Constr 5	0.00	2500.00	>=	0.00
Lower Bound	0.00	0.00		
Upper Bound	infinity	infinity		
Unrestr'd (y/n)?	n	n		
Integer (y/n)?	y	y		

Figure 1. Values for the constraints taken in TORA software.

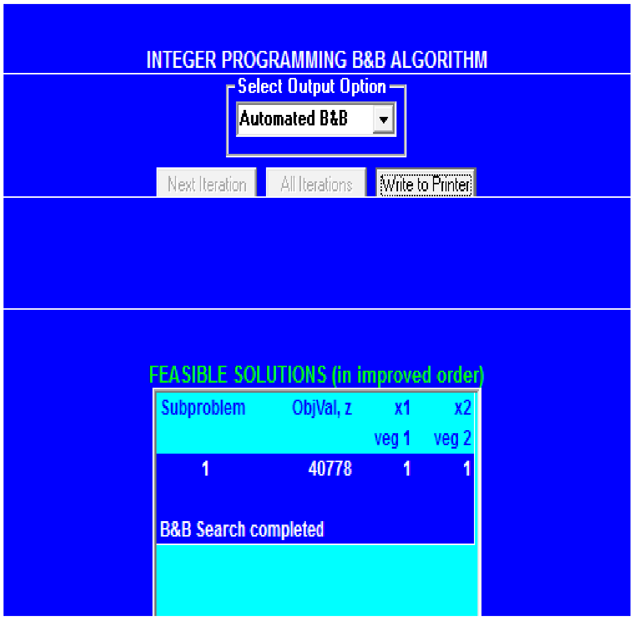

Figure 2. The output obtained from TORA software.

can be optimized right from CC to DC and from DC to various Retail outlets.

6. Results and Conclusion

The integer programming model done for optimizing the cost of distribution provides a feasible solution to the distributors and retailers and satisfying the demand at the same time. Thus, total cost can be minimized without affecting the efficiency of distribution. Further research in this area helps to reduce food wastage effectively by incorporating more accuracy in the model. The present study is done for APMC – Bengaluru which is one of the major vegetable markets. This model can also be used for other organizations like MORE, Reliance fresh, Big basket etc. to meet their vegetable demand and reducing the food waste considerably.

Cost optimization model can also be implemented by other distributors and retailers so that effective distribution takes place inside Bengaluru which also meets the demand of the retail stores accurately. As the demand is met, there will be considerable reduction of food loss at the retail stores also.

7. References

1. Daofang C, Jinfeng Z, Danping L. Cold chain logistics distribution network planning subjected to cost constraints. International Journal of Advanced Science and Technology. 2015; 75:1–10.
2. Lyons AC, Maaram A. An examination of multi-tier supply chain strategy alignment in the food industry, International Journal of Production Research. 2015; 52:1911–25.
3. Rong A, Akkerman R, Grunow M. An optimization approach for managing fresh food quality throughout the supply chain. International Journal of Production Economics. 2011; 131:421–9.
4. Hsu CI, Hung SF, Li HC. Vehicle routing problem with time-windows for perishable food delivery. Journal of Food Engineering. 2007; 80:465–75.
5. Akkerman R, Farahani P, Grunow M. Quality safety and sustainability in food distribution: a review of quantitative operations management approaches and challenges. OR Spectrum. 2010; 32:863–904.

6. Roghanian E, Sheykhan A, Abendankashi ES. An application of fuzzy TOPSIS to improve the process of SCM in the food industries: A case study of protein products manufacturing company. Decision Science Letters. 2014; 3:17–26.
7. Villarreal B, Garcia D, Rosas I. Eliminating transportation waste in food distribution: A case study. Transportation Journal. 2009; 48(4):72.
8. Bosona T, Gebresenbet G, Nordmark I, Ljungberg D. Integrated logistics network for the supply chain of locally produced food, part I: location and route optimization analyses. Journal of Service Science and Management. 2011; 4:174–83.
9. Cheshmberah M, Zahedia MR, Hadizadeh A, Tofighi SM. A mathematical model for optimum single-commodity distribution in the network of chain stores: a case study of food industry. Management Science Letters. 2011; 1:575–82.