Modelling and Analysing an Integrated Multi channel Food supply chain Distribution of an Indian Dairy Firm using Modified TLBO Algorithm

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Transportation related expenses forms a main chunk of product cost in a multi-stage manufacturing supply chain. The pressure on firms to reduce carbon emissions to go green had emerged in recent years due to government regulation, need for best possible allocation of available resources, competition from green players and rising awareness on environment protection in the minds of people. Given the increasing focus on emissions by several countries, we also incorporate an emission or pollution factor in our objective. Nowadays many manufacturers have started using more than one channel to connect with their customers to improve their reach; this led to the formation of multi-channel supply chains. Also, we attempt to deal with transportation related costs considering environmental issues while designing of a multi-channel supply chain of delivery system for a Dairy firm. Teacher-Learner-Based Optimization (TLBO) which does not involve any algorithm specific parameters is applied to solve the problem. The conclusion shows that levy flight distribution in teachers’ phase of TLBO performs better than traditional TLBO.

Keywords: Multi-Channel Supply Chain, Green, Dairy Firm, TLBO, Levy Flight

Introduction

Today integration is increasing between conventional retails and newer online channels cultivating a new type of customer behaviour. Effects of this behaviour on Multi channel are yet to be studied. Brick and mortar stores enable customer to have hands on experience before buying the new product and provide better service to the customers². It was identified that inventory management and logistics network as the basis for the operations of multi-channel operations². Satisfying customers as well as increasing revenue are the main reasons that persuade retailers to adopt a multi-channel strategy, even though the response of the retailers towards these factors may vary⁴. Recently, several nature-inspired metaheuristic techniques have been developed which had proved themselves capable of solving complex nonlinear optimisation problems efficiently, which was not possible with traditional algorithms⁵. Most important advantage of metaheuristics is that it doesn’t demand any properties in the objective function like continuity, convexity, differentiability. There is no universally best meta-heuristic technique for all different classes of Problems. It is proved for distribution centres allocation problem solved using traditional genetic algorithm(GA) and with an improved heuristic in which it is showed that modified heuristic improves the result of the problem compared with GA¹. Performance of swarm and evolutionary intelligence based optimization algorithms is highly affected by the selection of algorithm-specific parameters. But Teacher Learner Based Optimization (TLBO) whose main advantage being, that it’s basic and also doesn’t require algorithm-specific parameters. Hence, TLBO has been used for several engineering issues or problems for obtaining optimum results⁷⁸. Popular metaheuristic algorithm, Particle swarm optimization which is joined with Levy flight (PSOLF) enhanced the global search ability and convergence efficiency³. Also, it is found that Exploration and exploitation capabilities of Bat Algorithm are improved and balanced by introducing Levy Flight in the search process⁹. This paper tries to develop Mixed Integer Linear Programming (MILP) model for a multi-channel supply chain network and to solve the model, a novel Meta heuristic algorithm like TLBO algorithm is used. The outcomes from the work shows that the comparison of performance of traditional TLBO with TLBO with levy flight.

Problem description

Dairy firm supply chain

ABC Pvt Ltd. a southern part of India based diary firm is one of the leading producers of processed

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milk, which has its market presence throughout southern part of India. Recently they have integrated multi-channel system in their supply chain. They deliver milk products to different customer zones directly from their Ice cream plants and from delivering to their distribution centres (DC) apart from traditional offline channel.

The growth of online retailing led the company to add an additional channel to cater the online demands. Now the objective of this paper is to optimise the delivery system of this multi-channel supply chain through minimising logistics costs and carbon emission. The chilling centres are located in six locations because milk production is maximum in these areas. Hence, they are collected from these parts of the state and used all over the state. From the chilling centres they are transported to five processing plant for further uses. The processed milk is sent to plants located at different zone for other uses such as Ice cream production. There are five ice cream plants and seven distribution centres in total located in the state. From the distribution centre they are sent to customer market zone located in each district and the two e-channel cold rooms are located for satisfying the online channel demands. Figure 1 shows the supply chain model of the problem.

Methodology

Model description

A mathematical model has been formulated. Objective functions constraints are identified and is described as follows

Model assumptions

- The shipping cost for each product from one entity to other entity in the supply chain remains constant during entire time and varies only proportionally by the distance travelled.
- The distance between the distribution centres and e-channel cold rooms is neglected.
- Chilling centres and plants have unlimited capacity.

Sets and parameters

Sets:

I: set of chilling centre
J: set of plant
K: set of distribution centres
H: set of ice cream plants
M: set of e-channel cold rooms
R: set of retailers
L: set of customer market zone
X: Number of units (litres) of product

One unit of milk = one litre of milk

Parameters

Cij : Cost of transporting one unit of milk from chilling centre i to plant j
Cjh : Cost of transporting one unit of milk from plant j to ice cream plant h
Clk : Cost of transporting one unit of product from ice cream plant h to DC k
Clk : Cost of transporting one unit of product from ice cream plant h to customer zone l
Cml : Cost of transporting one unit of product from e-channel cold rooms to customer zone l
Ckr : Cost of transporting one unit of product from DC k to retailer r
Crl : Cost of transporting one unit of product from retailer r to customer zone l
Ri : Units of raw milk from chilling centres for converting one unit of processed milk at plants
Rs : Units of processed milk from plants for converting one unit of product at ice cream plants
Di j : Distance from chilling centre i to plant j
Djh : Distance from plant j to ice cream plant h
Dhl : Distance from ice cream plant h to customer zone l
Dhk : Distance from ice cream plant h to DC k
Dkr : Distance from DC k to retailer r
Drl : Distance from retailer r to customer zone l
Dml : Distance from e-channel cold room to customer zone l
Ck : Capacity of DC k
Cr : Capacity of retailer r
Ch : Capacity of ice cream plant h
Cm : Capacity of e-channel m
Td : Total demand of e-channel customer and retail customer

t : tax rate in Rs/kg of emission
E : emission rate between the entities during transporting the product in kg/tonne mile

Fig 1 — Supply chain model of the problem
Variables

- \( X_{ij} \): Number of litres of milk transported from chilling centre \( i \) to plant \( j \)
- \( X_{jh} \): Number of litres of milk transported from plant \( j \) to ice cream plant \( h \)
- \( X_{hl} \): Number of units of product transported from ice cream plant \( h \) to customer zone \( l \)
- \( X_{hk} \): Number of units of product transported from ice cream plant \( h \) to DC \( k \)
- \( X_{kr} \): Number of units of product transported from DC \( k \) to retailer \( r \)
- \( X_{rl} \): Number of units of product transported from retailer \( r \) to customer zone \( l \)
- \( X_{mI} \): Number units of product transported from echannel cold room \( m \) to customer zone \( l \)

- CIP: Binary customer zone gets the product from ice cream plant \( h \) directly
- CE: Binary customer zone gets the product from echannel cold room directly
- CR: Binary customer zone gets the product from retailer through offline

Mathematical model

In this case of food distribution system, the demand at the offline channel, demand at online e-channel cold room and demand at ice cream plant are considered with certainty. The objective function is given by the following equation

\[
\text{Minimize } Z = \sum_{i=1}^{I} \sum_{j=1}^{J} C_{ij} * X_{ij} + \sum_{j=1}^{J} C_{jh} * X_{jh} + \sum_{h=1}^{H} C_{hk} * X_{hk} + \sum_{k=1}^{K} C_{kr} * X_{kr} + \sum_{l=1}^{L} C_{pl} * X_{pl} + \sum_{l=1}^{L} C_{rl} * X_{rl} + \sum_{m=1}^{M} C_{ml} * X_{ml} + \sum_{l=1}^{L} t * E_{lj} * D_{lj} + \sum_{l=1}^{L} C\sum_{h=1}^{H} C_{hh} * D_{hh} + \sum_{l=1}^{L} \sum_{r=1}^{R} t * E_{kr} * D_{kr} + \sum_{l=1}^{L} C\sum_{m=1}^{M} C_{ml} * D_{ml} + \sum_{l=1}^{L} t * E_{hl} * D_{hl} + \sum_{l=1}^{L} t * E_{ml} * D_{ml}
\]

Constraints

- Capacity constraint for ice cream plants, distribution centres, retailers and e-channel cold room are given by
  \[
  \sum_{u} X_{uv} \leq C_{v}
  \]
- Equation is considered separately for \( u, v \in \{h, k, l\} \) and \( u, v \in \{h, k, l\} \) for \( k, (r, l) \) and \( r, l \) and \( u, v \in \{h, k, l\} \).
- No wastage at plant, ice cream plant, DC and Retailer is given by
  \[
  \sum_{i} X_{ij} = R_{i} \sum_{j} X_{jh} - R_{h}(\sum_{h} X_{hk} + \sum_{h} X_{hl}) = 0;
  \]
  \[
  \sum_{h} X_{hk} - (\sum_{m} X_{ml} + \sum_{k} X_{kr}) = 0 \text{ and } \sum_{k} X_{kr} = \sum_{r} X_{rl}
  \]
- Customer preference constraint to purchase either online at ice cream plant or e-channel or at retailer and customer demand constraint for all types of customers are given by
  \[
  \sum_{h} C_{IP} + \sum_{m} C_{E} + \sum_{r} C_{R} = 1 \forall l \text{ and } \sum_{h} X_{hl} + \sum_{m} X_{ml} + \sum_{r} X_{rl} \leq T_{d}
  \]

Pseudo code for TLBO with Levy flight distribution algorithm

For \( i=1 \) to \( D \)

\[ a \leftarrow \text{select a random integer in } \{1,2,...,NP\} \]

End

For \( k=1 \) to \( NP \)

IF \( r_{1} < 0.5 \) // Teaching

For \( i=1 \) to \( D \)

IF \( r_{2} < SP \)

\[ TF(i) = \text{round}(1 + r_{3}) \times (X_{best}(i) - T_{F}(i) \times M(i)); \]

End

End

Else // Learning each other between learns

For \( i=1 \) to \( D \)

IF \( r_{4} < SP \)

\[ r \leftarrow \text{select a random integer in } \{1,2,...,NP\} \]

IF \( X_{r} \text{ is better than } X_{k} \)

\[ X_{new}(i) = X_{k}(i) + r_{4} \times (X_{r}(i) - X_{k}(i)); \]

Else

\[ X_{new}(i) = X_{k}(i) + r_{5} \times (X_{k}(i) - X^{*}(i)); \]

End

EndIf

EndFor

Else // Learning each other between learns

EndFor

For \( i=1 \) to \( D \)

IF \( r_{5} < SP \)

\[ r \leftarrow \text{select a random integer in } \{1,2,...,NP\} \]

IF \( X_{r} \text{ is better than } X^{k} \)

\[ X^{k} = X^{\text{new}} \]

End

Where \( r_{1}, r_{2}, r_{3}, r_{4} \) and \( r_{5} \) are uniformly distributed.
random numbers between 0 and 1
NP - Population size
Tmax - Maximum evaluation times of objective function.
t - Current iteration times.
SR - Selection rate that new generated harmony instead of the worst harmony.
T - Cycle length for recalculating the SR.
c1/ c2 - Times of updating old solutions successfully of TLBO in the $t^{th}$ iteration.
r –Random number generated using levy distribution for TLBO with Levy algorithm and it is uniform distributed random number between 0 and 1 for traditional TLBO. Mantega algorithm is utilized for producing step sizes in levy distribution for exploiting the search.

Results and Discussions
The cost incurred due to the emissions in transportation shows in figure 3 (with 0% uncertainty) that the contribution due to the tax rate on emission is significant. Hence, we have been able to justify the move of organizations towards greener logistic systems. This, combined with the transportation cost leads us to a situation where maximum quantity of transportation over minimized distance gives us minimum overall cost. Taking this assumption in all allocations- from chilling centres to plants, from plants to distribution centre and from distribution centres to customer market zones, made while framing the model into consideration, the cost obtained out of this allocation is the optimal cost incurred in transportation for the forward supply chain of Dairy firm.

Details of total supply chain cost with and without green obtained through the modified TLBO and traditional TLBO are shown in Figure 2.

Conclusion
This paper tried to develop Mixed Integer Linear Programming (MILP) model for an integrated multi channel supply chain network of a dairy firm and to solve the model, a novel Meta heuristic approach like TLBO with levy flight algorithm is used. The objective of the problem that has been carried out, opted the multichannel integration along with the carbon emissions tax which significantly influences the cost incurred for the firm’s supply chain. First the deterministic model was constructed which uses tangible parameters and constraints to get order quantity allocations for its supply chain entities of dairy firm to minimize the total logistics cost. At last, the developed model for the problem was solved using modified TLBO algorithm which effectively eliminated the exploration and exploitation issues of traditional TLBO. As the next step, a global organization can be considered to make the logistics network more complex. The barriers to switching over to the proposed network can also be explored.

References