SCM Strategy for Sales Augmentation using TSP Algorithm and Time Bound Marginal Discount Utility

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***Abstract*— At present, Fast Moving Electrical Goods (FMEG) industries target wholesale dealers and not the retailers for supplying their finished goods. The reasons for this being: a) Dealers are fewer in numbers and hence net distance travelled per shipment is less, b) Dealers tend to demand higher lot sizes, thereby decreasing overall cost of transportation per unit for the product. This unique work presents a supply chain strategy to use retailer based distribution by solving both the issues by a) using the concept of milk runs by taking analogy of Travelling Salesman Problem to decrease transportation cost and b) applying time bound marginal discount utility to solve the issue of low lot sizes. A live case study has been prepared based on field experiences of middle level FMEG industry for its four popular consumer products. It presents a new application of travelling salesman problem (TSP) algorithm to make efficient milk runs. Also, concept of time bound marginal discount utility solution is proposed to find an optimum discount price to optimize the transportation cost and revenues. The paper compares this proposed supply chain strategy with manufacturer to dealer model and manufacturer to retailer model with various combinations.**

***Keywords*—** *Supply Chain Management, Travelling Salesman Problem, Marginal Discount, Forward Buying, Milk Runs*

1. Introduction

The improvement of supply chain performance and efficiency has always been a subject of exciting challenge for all industries on both buy side and the sell side [1].

The transportation cost and time taken to deliver the goods exactly as per the market demand are the two main factors which the supply chain management (SCM) experts always strive to focus for optimization [2]. There is therefore increasing evidence of the growing importance of supply chain design [3]. Moreover study and use of information technology have contributed to further improvements in supply chain performance.

FMEG industries conventionally follow manufacturer to dealer to retailer based distribution system. The primary advantage of this system is that dealers are less in numbers hence distance travel per shipment is less. Moreover dealers demand higher supplies so as to make distribution even more effective. Milk runs are fundamental choice for any distribution system. It is the process of consolidating different orders from various dealers/retailers done to increase truckload efficiency and reduce transportation cost [4]. The no of trips, vehicle routing and vehicle load are required to be treated with mathematical modelling to make milk runs more efficient and effective [5, 6]. Also study is found on the productivity of sales force to increase sales and thereby the supply chain efficiency on the selling side [7]. There are studies on the subject of distribution network design that helps to choose the suitable network for the given product segment that an organization finds itself in [8]. The competition these days is not among organizations but between supply chains [9, 10].

A case study is presented to work out a way to move beyond dealers in supply chain network to make it economically more profitable and to penetrate deeper and wider in the marketplace. It is based on live business problem of shifting from dealer based distribution to retailer based distribution. This complicates the business relationship with dealers at the cost of increased transportation. One of uniqueness of this study is the application of milk run concept through mathematical analogy with travelling salesman problem theory. Discount to retailers is provided

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and the discount amount is decided by running all possible combinations for a perfect trade-off between revenue and transportation cost. Optimization is achieved using application of Matlab software.

The concept of time bound marginal discount utility (TBMDU) is introduced to shift demand. A discount is provided to each product. This promotion is only for that week. In order to gain from the situation the dealers/retailers are believed to make efforts to stock up inventory. The discount is strategically provided such that the inventory at dealer/retailer end reaches zero stock levels when the discount is provided again.

Detailed design is presented in section 2.0 and different case studies are presented in section 3.0. Results and conclusion are presented in section 4.0 and 5.0.

2. Detailed Design of distribution network

The design involves the implementation of SCM strategy for transit from dealer distribution system (DDS) to retailer distribution system (RDS). Hybrid models when applied innovatively can be useful and the same has been used in designing the distribution system. A similar model is presented for fashion industry for accurate forecasting. In this work a hybrid model is suggested using milk runs and time bound discount scheme to augment sale [11].The design of supply chain plays an important role in improving its efficiency and performance just as strategic purchasing positively influences its operations and firm performance [12].To solve it in mathematical way, following scenario and assumptions are considered

Table 1: SCM data for four electrical products

	A	**B**	**C**	D
Weekly Demand (Units)	765	471	540	200
Mfg cost (Rs)	180	168	178	144
SPD (Rs)	200	181	195	178
Net Firm Profit (Rs)	20	14	17	34
SPR (Rs)	206	185	200	186
Dealer Profit (Rs)	6	4	5	8
Market Price (Rs)	210	188	205	190
Retailer Profit (Rs)	4	3	5	4

- There are 4 products namely Miniaturized Circuit Breaker (A), Electric Razor (B), Electrical Switch (C) and Down Lighter (D). Each product has an independent weekly demand, manufacturing cost, selling price to dealer (SPD), and selling price to retailer (SPR) and. dealer profits. Table 1 shows SCM data for these products being sold by the company. Herein we denote Net Firm Profits as
- Orders come in on a weekly basis and the company sends the shipments only once every week.
- There is one manufacturer, four dealers and thirty retailers. Locational coordinates of each are known.
- Net annual profit which denotes final profit of the firm is used as parameter to compare profitability of various cases. This is equivalent to EBITDA (Earnings Before Interest Taxes Depreciation & Appreciation).
- All the conclusions and results are evaluated without considering non-quantifiable factors like relationships between manufacturer/dealer/retailer (M/D/R). The information technology system in the company across suppliers, manufacturing plant, dealers and retailers is adequate to support proper information flow and information quality [13].
- Complete aggregation model is followed by the manufacturing plant.
- Transportation cost of truck is assumed to be independent of truck load. Transportation Cost is taken as 25 per km. This includes fuel, permit, loading and unloading costs and wages of drivers.
- The coordinates for four dealers and 30 retailers are given in Table 2. These are on a scale 1 unit = 3 km. A geographical representation is shown in fig. 1.
- Holding cost is taken as 0.1. This is taken in analogy to discount rate of 10% being followed while calculating Net Present Value (NPV)
- Maximum truckload capacity is not taken into consideration.
- Forward Buying: Dealers/Retailers moving up future purchases to the present. This however, does not increase any sales in long run

Table 1: Location coordinates of Manufacturers / Dealers / Retailers

	X	Y		X	Y
M	0	0	R14	-25.5	5
D1	12.5	12.5	R15	-12	0

D2	-17.5	12.5	R16	-8	-8
D3	-12.5	-12.5	R17	-16	-3
D4	12.5	-7.5	R18	-23	-4
R1	14	5	R19	-23	-13
R2	27.5	8	R20	-23.5	-21.5
R3	25	18	R21	-11	-21
R4	16	25	R22	-2	-17
R5	14	17.5	R23	6.5	-2.5
R6	6	7	R24	6.5	-11.5
R7	6	18	R25	8	-18.5
R8	-8	8	R26	16.5	-15
R9	-7	12.5	R27	23	-20
R10	-7	25	R28	25	-11
R11	-26	22	R29	26.5	-4
R12	-17.5	21.5	R30	16	-2
R13	-23.5	14.5			

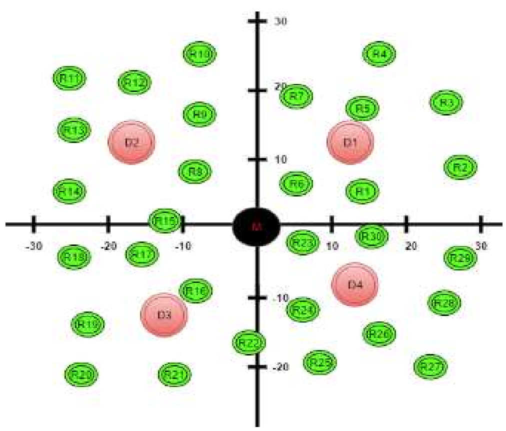

Fig 1: Geographical representation of M/D/R location

2.1 Travelling Salesman Problem(TSP)

2.1.1 Introduction to TSP

The TSP asks the following question "Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city exactly once and returns to the origin city?"

Let 1,2,3…,n be the labels of the n cities and C = C_{ij} be an n * n cost matrix where C_{ij} denote the cost of traveling from city i to j. Then, the general formulation of the TSP is shown below

	1	2	3	….	n
1	∞	C_{12}	C_{13}	…	C_{1n}
2	C_{21}	∞	C_{23}	…	C_{2n}
3	C_{31}	C_{32}	∞	…	C_{3n}
..	…	…	…	∞	…
n	C_{n1}	C_{n2}	C_{n3}	…	∞

2.1.2 Mathematical Model of TSP

Starting from his home, a salesman wishes to visit each of (n 1) other cities and return home at minimal cost. He must visit each city exactly once and it costs Ci j to travel from city i to city j. We may be tempted to formulate this problem as:-

$$X_{ij} = \begin{cases} 1 \text{ ; if he goes from city i to j} \\ 0 \text{ ; otherwise} \end{cases}$$

Mathematical Formulae comes out to be:-

$$\text{Min } Z(X) = \sum_{i=1}^{n} C_{ij} X_{ij}$$

Subject to constraints:-

$$\sum_{i=1}^{n} X_{ij} = 1 \text{ for } i = 1 \dots n$$

$$\sum_{j=1}^{n} X_{ij} = 1 \text{ for } j = 1 \dots n$$

$$X_{ij} \geq 0, \text{for all i, j}$$

$$X_{ij} = 0, \text{for all i, j}$$

2.1.3 Algorithm to solve TSP

1. Divide each row by $\sum_{i=1}^{n} a_{ij}$
2. Divide each row by $\sum_{j=1}^{n} b_{ij}$
3. Check optimality(draw lines to cover all one) if it is equal to *n* then go to last step
4. If drawn lines *n*, then consider all element less than 1.5 matrix as 1, and again check optimality
5. If still drawn lines *n*, then choose smallest element d_i from uncovered row or column and divide this d_i from uncovered row or column
6. Repeat second last step until optimum solution is attained

3. Case Studies

3.1 DDS with no milk runs

In this model an independent truck is sent to each dealer as shown in the fig-2 below:

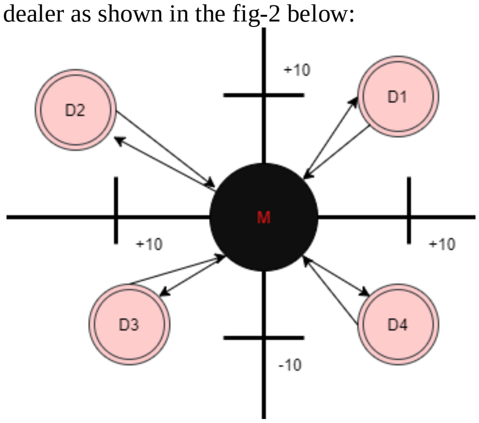

Fig 2: Truck movement for each dealer

The distance between the manufacturer and dealer is calculated as under:

Distance between two points is given by:- =

$$\sqrt{((x_1-x_2)^2 + ((y_1-y_2)^2} \qquad (1)$$

The total distance to be travelled comes to 429.12 kilometres.

The firm profit is calculated as under:

Net Firm Profit for DDS

$$= \sum_{i=1}^{4} \text{Per Week Demand}_i * \text{Firm Profit} * \text{No. of Weeks} \qquad (2)$$

The net firm profit for 1 year (52 weeks), comes out to be Rs. 19,69,488.

The net transportation cost is calculated through the following formula:

$$\text{Net Transportation Cost} = \text{Net Distance} * \text{Cost per kms} * \text{No. of Weeks} \qquad (3)$$

This gives the net transportation cost as Rs. 5,57,856.

The net Annual profit is worked out as under :

$$\text{Net Annual Profit} = \text{Net Firm Profit} - \text{Net Transporation Cost} \; (4)$$

This gives annual profit as Rs. 14,11,592.

3.2 DDS with milk runs

As orders come on a weekly basis. Taking advantage of the fact that all orders need to be dispatched on the same day, the firm decided to go for milk runs approach as illustrated in Fig. 3.

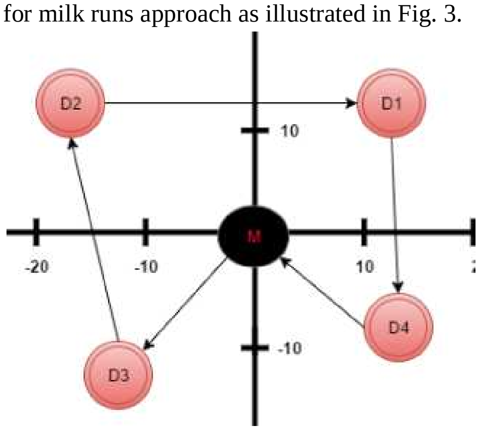

Fig 3: Milk Runs approach for DDS

As there are 4 dealers there are 4!/2 possible combinations. Removing obvious cases when truck goes from D1 - D3 and D2 - D4 we get 4 cases left. Finding distance using equation (1) we get minimum distance of 323.28 kms for M-D4-D1-D2-D3-M. Net firm profit remains the same but net transportation cost reduces to Rs. 4,20,264. Equation (4) gives net annual profit of Rs. 15,49,184 **.** Table 3 presents sum of individual trips for four different cases

Cases	Sum of Trips (kms)
M-D1-D2-D3-D4-M	348.48
M-D1-D4-D3-D2-M	339.48
M-D2-D1-D4-D3-M	352.98
M-D3-D2-D1-D4-M	323.28

Table 3: Sum of individual trips for four cases

3.3 RDS with no milk runs

In this model an independent truck is sent to each retailer in shown in Fig. 4.

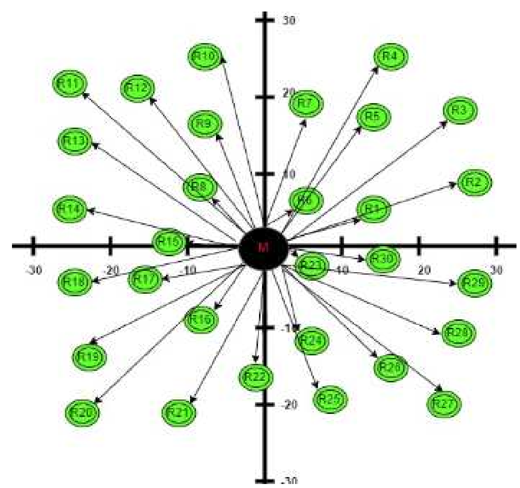

Fig 4: Graphical representation of RDS with no milk runs

This results in long commute distance which results in high transportation cost. .

To find net firm profit for 1 year (52 weeks), the following formula is used :

Net Firm Profit for

$$\text{RDS}=\sum_{i=1}^{4}\text{Per Week Demand}_i * (\text{Firm Profit} + \text{Dealer Profit}) * \text{No. of Weeks} \quad (5)$$

This gives the net firm profit as Rs. 25,29,696. Using equation (1) to find distance between manufacturer and each dealer, net distance comes to 3881.742 kms. Using equation (3), net transportation cost is Rs. 50,46,268.50. Using equation (4), net annual profit comes out to be Rs. -25,16,572.50.

3.4 RDS with milk runs

Next case is taken as RDS with milk runs. Again taking advantage of milk run systems, the firm reduces its transportation cost. However, on transiting from dealer to retailer it is observed that performing permutations will lead to exceptionally high number of cases. Number of cases for such a problem comes out to be 30! /2 = 10^34 order. Even if we program to check for all possible cases the above problem will take thousands of years to solve. This problem is hence solved by comparing it with TSP. Table 4 gives optimum order that needs to be followed. Minimum distance comes out to be 299.16units. This is equal to approximately 900 kms. Net firm profit remains same as in case 3.3. Net transportation cost comes to Rs.11,70,000. Calculating net firm profit gives value of Rs.13,59,696.

Retailer	X	Y	Distance
M	0	0	
R6	6	7	9.219544
R1	14	5	8.246211
R2	27.5	8	13.82932
R3	25	18	10.30776
R4	16	25	11.40175
R5	14	17.5	7.762087
R7	6	18	8.01561
R8	-8	8	17.20465
R9	-7	12.5	4.609772
R10	-7	25	12.5
R12	-17.5	21.5	11.06797
R11	-26	22	8.514693
R3	-23.5	14.5	7.905694
R14	-25.5	5	9.708244
R15	-12	0	14.39618
R17	-16	-3	5
R18	-23	-4	7.071068
R19	-23	-13	9
R20	-23.5	-21.5	8.514693
R21	-11	-21	12.51
R16	-8	-8	13.34166
R22	-2	-17	10.81665
R24	6.5	-11.5	10.12423
R25	8	-18.5	7.158911
R26	16.5	-15	9.192388
R27	23	-20	8.20061
R28	25	-11	9.219544
R29	26.5	-4	7.158911
R30	16	-2	10.68878
R23	6.5	-2.5	9.513149
M	0	0	6.964194
Net Distance			299.16

3.4 DDS with milk runs and TBMDU

In this particular case, the goods are distributed to dealers using milk runs and to facilitate Full Truck Load (FTL) the discounts are given to encourage forward buying.

The increased demand at a specific discount is calculated as under:

$$= Q^d = \frac{dD}{(C-d)h} + \frac{CQ^*}{C-d} \quad (6)$$

where,

Q^* : Normal Order Quantity
C: Normal Unit Cost
d: Short Term Discount
D: Annual Demand
h: Cost of Holding Rs 1 per year

Q^d : Short Term Order Quantity
$Q^d - Q^*$: Forward Buy

Though the Eq (6) is primarily used with no future discounts are announced but this situation takes into account the completion of forward buying before giving next discount.
The net firm profit and transportation cost with TBMDU of the firm are calculated as under:

Net Firm Profit for DDS using TBMDU =

$$\sum_{i=1}^{4} \text{Per Week Demand}_i * (\text{Firm Profit} - \text{Marginal Discount}) * \text{No. of Weeks} \quad (7)$$

Net Transportation cost under TBMDU =
Next Integer of Maximum trips required for each product * Net Distance * Cost per km (8)

No. of Trips required for a Product =

$$\frac{\text{Average Weekly Demand} * \text{No.of Weeks}}{\text{Short Term Discount}} \quad (9)$$

As the discount for each product is increased net transportation cost as well as net firm profit starts to decrease. This problem is dealt by generating a MATLAB code to simulate for large combinations by changing values of discount for each product.

Precision levels:-

- Product A Discount: 0.01
- Product B Discount: 0.01
- Product C Discount: 0.01
- Product D Discount: 0.01

Constraint equations:-

- Product A Discount ≤ Firm Profit for A
- Product B Discount ≤ Firm Profit for B
- Product C Discount ≤ Firm Profit for C
- Product D Discount ≤ Firm Profit for D

Optimum values were obtained in the Table-4 as follows:-

Table 5: Optimum Values

Product	Short Term Discount	Short Term Demand	No. of Trips
A	0.95	666.80	14.91
B	0.86	410.62	14.91
C	0.92	468.40	14.98
D	0.84	173.51	14.98

These optimum values give net firm profit if Rs18,76,924, net transportation cost of Rs 1,21,230 and hence net annual profit of Rs 17,54,794.

3.5 RDS with milk runs and TBMDU

In this case study, the goods are distributed to retailers using milk runs and to facilitate FTL, the discounts are given to encourage forward buying.

The net firm Profit with TBMDU of the firm are calculated as under:
Net Firm Profit for RDS using TBMDU =

$$\sum_{i=1}^{4} \text{Per Week Demand}_i * (\text{Firm Profit} + \text{Dealer Profit} - \text{Marginal Discount}) * \text{No. of Weeks} \quad (10)$$

As the discount for each product is increased net transportation cost as well as net firm profit starts to decrease. This problem is dealt by generating a MATLAB code to simulate for large combinations by changing values of discount for each product.
Precision levels:-

- Product A Discount: 0.01
- Product B Discount: 0.01
- Product C Discount: 0.01
- Product D Discount: 0.01

Constraint equations:-

- Product A Discount ≤ Retailer Profit for Product A
- Product B Discount ≤ Retailer Profit for Product B
- Product C Discount ≤ Retailer Profit for Product C
- Product D Discount ≤ Retailer Profit for Product D

Optimum values were obtained as given in Table 6:

Table 6: Optimum Values

Product	Short Term Discount	Short Term Demand	No. Of Trips
A	1.65	132.77	9.98
B	1.48	81.66	9.99
C	1.60	93.62	9.99
D	1.49	34.71	9.98

These optimum values give net firm profit if Rs 23,67,386, net transportation cost of Rs 2,25,000 an hence net annual profit of Rs 21,42,386.

4. Results

The net firm profit and transportation cost calculated in each case study have been summarized into the table 7**.** The resultant net annual profit has been used as the main criteria to determine the most suitable model for our increasing the sales of the products.

Table 7: Net annual profit for different cases

Case No.	Net Firm Profit (Rs)	Net Transportation Cost (Rs)	Net Annual Profit
1	19,69,448	5,57,856	14,11,592
2	19,69,448	4,20,264	15,49,184
3	25,29,696	50,46,268.5	(25,16,572.5)
4	25,29,696	11,70,000	13,59,696
5	18,76,024	1,21,230	17,54,794
6	23,67,386	2,25,000	21,42,386

Table 8: Comparison of different cases

Case Comparison	Change in Net Profits	Change in Net Transportation Cost	Change in Annual Firm Profits
2 vs 5	**-93,423.72**	**-299,034**	**205,610.28**
4 vs 6	**-162309.16**	**-945,000**	**782,690.84**

Table 8 compares this case study for effect of TBMDU on DDS and RDS. This leads to a positive effect overall. However it is noticed that it has a greater effect in the case of RDS than DDS. This is because of much more significant change in transportation cost for RDS (Rs 9,22,500) than DDS (Rs 2,99,034).

5. Conclusions

1. Negative cash flows in Case 4 show that RDS is not feasible without approaching milk runs.
2. Milk Runs systems can be solved using TSP with a high degree of accuracy.
3. DDS with Milk Runs is more profitable without any provision of discount than RDS with Milk Runs. This is mainly due to the high transportation cost which surpasses the added profits generated by disintermediation
4. TBMDU technique has a positive impact in both the cases, but more in case of RDS.
5. This strategy mainly targets at reducing transportation cost significantly by compromising on profit margins.
6. Factors that allow such a SCM strategy to be adopted include
    - Coordinates of Manufacturers, Dealers & Retailers
    - Average Transportation Cost per km
    - Manufacturing cost of product
    - Firm profit
    - Dealer profit
    - Market price
    - Holding cost of capital

Thus this case study presents the unique work on optimization of distribution network of fresh goods in which milk runs and marginal discount utility concepts have been applied. This therefore becomes an extremely useful document for modern day supply chain experts to be read along with those works which are related to reverse logistics [14].

One interesting study for future is to find out the extent to which the suggested retail distribution model can facilitate in taking back defective goods. Reverse logistics these days has come to be an extremely significant part of efficient, profitable and Green supply chains [15, 16].

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