Vehicle routing and capacity planning at DMist dairy do-operatives

Introduction

The vehicle routing problem with different variations has been widely studied in the literature. This case provides an opportunity for solving a hypothetical problem of non-stochastic demand to be fulfilled within a limited time window by an appropriate/ optimal number of heterogeneous capacity vehicles with an objective of route and vehicle capacity optimization. The case is about DMist dairy co-operatives that manage hundreds of co-operative societies involved in animal husbandry and milk production activities.

Mr. Amit Jain is on his way to home after taking charge of his position as Chief Operating Officer (COO) at DMist Dairy Co-operatives. On his first day at DMist, Mr. Jain met many of his sub-ordinates and discussed ongoing problems and challenges at DMist. One of the challenges that Mr. Jain come to know is that over the past few months, vehicle owners are reluctant to provide their services to transport cattle feed from DMist's cattle feed plants (CFP) to milk societies. This is because of the uneven loading of their vehicles and re-imbursement structure of the DMist for transporting the fodder from CFP to milk societies. While discussing with subordinates on the first day, Mr. Jain also looked at the number of vehicles generally

Copyright © 2016 Shri Dharmasthala Manjunatheshwara Research Centre for Management Studies (SDMRCMS), SDMIMD, Mysore. This case is published as a part of 'Cases in Management Volume 5 (2016)' with
ISBN 978-93-83302-22-2

The case writer(s) Ram Kumar Dhurkari, Assistant Professor -Operations may be reached at ram@sdmimd.ac.in Author(s) have prepared this case as the basis for class discussion rather than to illustrate either effective or ineffective handling of the situation. This case is fictionalized and any resemblance to actual person or entities is coincidental. This publication may not be digitized, photocopied, or otherwise reproduced, posted, or transmitted, without the permission of SDMRCMS, SDMIMD, Mysore. For Teaching Notes please contact sdmrcms@sdmimd.ac.in.

used to fulfill the fodder demand of milk societies. Mr. Jain is still wondering about the number of vehicles involved in the regular transportation of cattle feed from DMist's two CFPs to various milk societies. According to Mr. Jain, the number is huge and can be minimized by optimally loading and routing vehicles to various milk societies. Mr. Jain immediately makes a call to Mr. Ravi Sharma, Operations Manager (Fodder Processing and Distribution) and responsible for managing the processing, packaging and distribution of fodder from both the CFPs. Mr. Jain instructs Mr. Sharma to explore any possibility of reducing the number of vehicles for cattle feed distribution and update on the same by next day afternoon.

DMist Dairy Co-operatives

DMist is one of the popular brands of milk and related products in one of the state of India. DMist has unmatched quality and standards. DMist has processing units and societies in all the villages and towns of the state to procure, process and sale milk and related products, giving employment and prosperity to a large number of small and marginal farmers. DMist was established in 1990 with an objective for collaborative milk production, distribution and sale. One of the founding principles of DMist is 'of the People, by the People and for the People'. DMist mission is to render true service to the society while ensuring that it does not incur losses. Few of the objectives of DMist are

- To channelize surplus milk and related products from the rural areas to the urban consumers
- To maximize the returns to the milk producers of rural areas
- To promote milk production for the economic development of farming community
- To build up a co-operative and sustainable dairy community in the state

Currently, DMist has 3100 milk cooperative societies spread across the state with milk procurement of 1.2 million liters of milk per day. DMist has 15 milk processing plants with a combined processing capacity of 1.4 million liters of milk per day. DMist also has a milk powder plant having a capacity of production of 8 Metric Ton of milk powder per day. DMist also has two Cattle Feed Plants (CFP) having a combined capacity of producing 500 Metric Ton of cattle feed per day. The cattle feed produced in these plants are well accepted by the dairy society farmers and the open market.

Cattle Feed Distribution from CFP

DMist has two CFPs at two different locations. The feed is distributed to various societies engaged in animal husbandry and milk production across the state by hiring private vehicles. Societies generally send their demand in advance to any of the nearest CFP. It is a routine task at both the CFPs to collect the demand from different societies and fulfill them through available vehicles and inventory of fodder.

At present, vehicle allocation to fulfill demands is done manually. A team of individuals manually allocates the demands to be fulfilled by various vehicles. This is done by a rough calculation for fulfilling a demand (or a combination) by a vehicle having certain maximum capacity. Because of this rough calculation, vehicle capacities are most often underutilized, resulting into excess number of vehicles required to serve the fodder demand of societies. Demands are not sliced currently, which means that if the demand of a society is less than the maximum vehicle capacity, it is required to be served by a single vehicle. Because of larger number of demands and vehicles, the individuals involved in vehicle assignment usually does not take pain to break or split the demands to be fulfilled by more than one vehicle. Further, often vehicles are loaded with fodder to fulfill demands of societies that are sparsely located from each other. Because of this uneven allocation, vehicles are required to move larger distances with fewer loads over some segments of the network of societies resulting into underutilization of vehicles.

In addition, the pricing model encourages vehicle owners to overload in order to maximize their revenues from a vehicle. For example, vehicle owners are paid only based on the amount of fodder (in kg or bags) carried per kilometer multiplied by some factor, which is determined by total km traveled to fulfill a demand location. The shortest route and distance from CFP is calculated in advance but it is not necessarily for the vehicle drivers to follow the same shortest route. However, they will be paid according to the shortest route only. Therefore, DMist cannot optimize the amount to be paid to each vehicle owner even after optimizing the number of vehicles. For example, suppose three demand locations A, B and C located at a distance of 20km, 130 km and 220 km from the source having demand of 60, 120 and 180 bags of fodder. DMist uses distance slab table as given in the Table 1, which helps in assigning a km rate multiple to calculate the amount to be paid for transportation of fodder (Table 2), assuming that a vehicle can supply to any number of demand locations.

Table 1:
Distance slab used by DMist

Kilometer (KM) range	Rate Multiple
Up to 100 KM	4.4
101 to 200 KM	3.3
201 to 350 KM	2.75
Above 350 KM	2.2

Table 2:
Calculation of amount to be paid to vehicle owners to supply

Demand Location (1)	Weight (in bags) (2)	Weight multiple (Weight/20) (3)	Distance (in km) (4)	Distance multiple (5)	Amount (3)*(4)* (5)
A	60	3	20	4.4	264
B	120	6	130	3.3	2574
C	180	9	220	2.75	5445
				Total	**8283**

Further, assuming that the demands are received in advance, they have to be fulfilled with in a limited period. If the demanding society is located farther, the demand has to be fulfilled considering the transit time also. Assuming that the transit time to all destinations is less than the chosen fixed time window within which the demand is to be fulfilled. Demands having high transit time need to be given high priority. The latest day by which the demand is to be fulfilled is calculated by the following formula.

Arrival date of demand + time window in days – transit time in days

Therefore, all demands which require to be fulfilled (latest by) today should be given high priority.

Optimizing vehicles for fodder distribution

Next day afternoon, Mr. Sharma briefs Mr. Jain about the possibility of reducing the number of vehicles by optimally loading them. During the discussion, Mr. Sharma list down a list of questions that need to be addressed to optimally load vehicles. The questions are

1 Which set of demand locations to be served by a vehicle

2 How much total load will be carried by each vehicle

3 How much load will be delivered by each vehicle to different demand locations

4 Which demands to split for filling the small unused vehicle capacities

Mr. Sharma explains

Considering a single source supplying finished goods to a network of destinations, it is required that the vehicle capacities are utilized optimally and all such vehicles should fulfill demand locations that are nearby each other. If the destinations to which a vehicle is going to supply finished goods are not nearby, vehicle may have to travel larger distances with unused capacities. Selecting an unfulfilled demand location and traversing the network to identify all unfulfilled demand locations within the vicinity (up to 3 levels or up to three intermediate demand locations in all directions) of the initial selected demand location will give as a sub-network of demand locations for which the vehicles can be optimally loaded. It is often that optimal loading is not possible considering total demand of a particular location as a whole. Such demands must be splitted to minimize the unused capacity of vehicle because vehicles cannot be overloaded. Vehicle routing and scheduling problem (VRSP) is widely studied in literature. For non-stochastic demand to be fulfilled by optimum number of heterogeneous capacity vehicles with an objective of route and vehicle capacity optimization, most of the studies do not reflect upon following two major questions simultaneously.

1. Suppose some material is required to be delivered (with known demands) to a network of destinations by a fleet of vehicles, then how to allocate optimally the available vehicles in order to deliver material within required time window to destinations that are nearby to each other?

2. How to prepare a split plan of material so that it can be loaded optimally in more than one vehicle and delivered within required time window?

Mr. Jain then asks

I appreciate your knowledge on this issue. However, I wonder whether that is possible using computer machine? Is it possible to have a computer application that when loaded with data can generate an allocation plan? And before that, why don’t you come out with an algorithm, required data structures in combination with some optimization technique which can perform this allocation and minimize the unused capacity of vehicles. You are also required to show the effectiveness of the same. Moreover, make sure that the splitting of demand should be the last option.

Mr. Sharma comments

Yes off course. My team can develop an application and before that, an algorithm that can do an optimal allocation of vehicle to various demands based on their locations. I did some analysis today morning and come out with required data structure on a partial representative network of milk societies (Exhibit 1 and Exhibit 2). I also have past data about demands of these societies and the vehicles available to fulfill these demands (Exhibit 3 and Exhibit 4). I shall develop the algorithm in combination with some optimization technique and see whether it can lead to reduction in number of vehicles for the same set of demands. Off course, we cannot optimize our bill but at least we can reduce the number of vehicles and the cost of transportation to vehicle owners so that they will not refuse to serve us.

Mr. Jain replies

Therefore, we are meeting again after a week to discuss the algorithm, the data structures and the optimization technique to take it further.

Mr. Sharma takes a deep breath saying that

Oh! Sure, I will try my best..

Exhibit 1

Variables*

Nsplit- it is a number that indicates the number of splits allowed for a demand

Minthr – Minimum threshold empty space (in kg) acceptable in any of the vehicle

Nlvl – it is a number that indicates up to what level the connection is explored from an initial non-zero demand identified (which is considered to be at zero level).

remcap - record the remaining capacity in a vehicle

C1,C2…..Cm be the vehicle maximum capacity,

d1, d2, …….dn are the demands of the currently selected nearby set of demand locations and

ds1, ds2…….dsn are the integer variables indicating which of the demands among d1, d2……..dn selected

to be assigned to the current vehicle with capacity C

*Note: Additional variables may be required

Exhibit 2

A Sample Connection Matrix of Milk Societies

(Diagonal cells represent current demand of respective society)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
5	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
6	5	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7	6	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	7	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	8	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
11	10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
12	11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
13	12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
14	13	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
15	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0

Sheet1 Sheet2 Sheet3 Sheet4 Sheet5 Sheet6 Help

Exhibit 3

A sample of cattle feed demand of few societies

	A	B	C	D	E	F	G	H	I
1	Code	Society	Demand	Demand Date	Latest By	Delievery Travel Time	Distance (KM)	Rate	DistanceXRate
2	1	ABC	4	23-Jun-11	26-Jun-11	0	77	2.2	169.4
3	2	BCD	72	25-Jun-11	27-Jun-11	1	29	3.3	95.7
4	3	CDE	40	23-Jun-11	25-Jun-11	1	8	4.4	35.2
5	4	DEF	9	23-Jun-11	26-Jun-11	0	85	2.2	187
6	5	EFG	40	25-Jun-11	27-Jun-11	1	68	2.2	149.6
7	6	FGH	50	24-Jun-11	26-Jun-11	1	20	3.3	66
8	7	GHI	55	25-Jun-11	27-Jun-11	1	35	2.75	96.25
9	8	HIJ	4	23-Jun-11	26-Jun-11	0	68	2.2	149.6
10	9	IJK	54	23-Jun-11	25-Jun-11	1	25	3.3	82.5
11	10	JKL	10	25-Jun-11	28-Jun-11	0	86	2.2	189.2
12	11	KLM	25	24-Jun-11	27-Jun-11	0	16	4.4	70.4
13	12	LMN	100	25-Jun-11	27-Jun-11	1	65	2.2	143
14	13	MNO	29	24-Jun-11	27-Jun-11	0	20	3.3	66
15	14	NOP	59	22-Jun-11	25-Jun-11	0	75	2.2	165
16	15	ABC	38	24-Jun-11	26-Jun-11	1	77	2.2	169.4

Sheet1 Sheet2 Sheet3 Sheet4 Sheet5 Sheet6 Help

Exhibit 4

A sample list of vehicles available to fulfill demands

	A	B	C
1	Truck No	Max Capacity	Truck Code
2	XY-25-2766	320	T1
3	XY-28-9025	320	T2
4	XY-10-0892	320	T3
5	XY-12-3797	320	T4
6	XY-14-7503	320	T5
7	XY-16-8958	320	T6
8	XY-08-8146	320	T7
9	XY-28-3506	320	T8
10	XY-29-3837	320	T9
11	XY-21-9266	320	T10
12	XY-29-5494	320	T11
13	XY-06-3039	320	T12
14	XY-21-3249	320	T13
15	XY-23-1895	200	T14
16	XY-28-5198	200	T15
17	XY-25-9767	200	T16