Designing an Optimal Cafe Delivery Network Using Travelling Salesman Problem

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Abstract— The aim of this work is to design a delivery network for Coffee Café's across the city using the travelling salesman problem so as to arrive at an optimal model. This will reduce the distance travelled by the delivery trucks and the associated costs incurred. Also, the number of trips taken by the delivery trucks should be reduced so as to accommodate emergency deliveries which are very much prevalent in the café chain business.

The considered Coffee Café has two warehouses in the city of Bangalore. The mother warehouse caters to the "regional warehouses" located across the country and the city warehouse caters to café's across the city. Though both cafes handle same type of material, only the city warehouse caters to the café's in the city. This effectively means that a café located near the mother warehouse would still be served by the city warehouse. Hence this arrangement is not ideal and leads to unnecessary and extensive transportation costs.

This work brings forward a proposal to break down the distribution model into two different networks with two different servers rather than one. We have made use of the Travelling Salesman Problem to find the optimal routes so that the new model is optimally and technically sound. Further we divided the café's into two groups per warehouse (high and low demand cafes). The low demand cafes were served once in two weeks compared to the existing system thus reducing the number of trips taken.

Keywords—Design, delivery network, warehouses, distance travelled, number of trips.

I. INTRODUCTION

The work was carried out in Bangalore for one of the leading Coffee Café chains in India which has over 1400 outlets throughout the country. It is also the 4th largest in Asia in terms of coffee exports.

This Coffee Cafe aspires to be the best Café chain by offering a world-class coffee experience at affordable prices. The chain also has has international presence with 16 café's outside the country i.e. two in Austria, two in Pakistan and ten café's in the Czech Republic. The chain has won numerous awards for its sustained excellence and continues to lead the Indian market unchallenged.

PROBLEM STATEMENT

The Coffee Café considered for this work owns two warehouses in the city of Bangalore (both urban & rural). The Mother Warehouse caters to the regional warehouses located across the country and the City Warehouse caters to all the café's located across Bangalore city. All the cafes are replenished once a week through a crew of three trucks which operate on a daily basis, six days a week

The problem's observed are

(1). Currently the schedules and Routes are operational without using any scientific techniques or methods. The trucks travel a combined distance of 3373 kilometres per month and the company wants to cut down on this. Also, there are two warehouses in the city which handle the same material. However, only one caters to the cafe's located across the city. The distance between the two warehouses is 27.8 kilometres. Thus, this gives rise to unnecessary and extensive transportation costs.

(2). The other concern for the management was a lack of operational vehicles in case they needed to make emergency deliveries with respect to shortage of stock or damage to goods etc. With the current delivery schedule, the three trucks make three trips a day, one per truck. This way, they make 72 trips a month (considering four weeks per month).

II. EXISTING MODEL

The existing milk run model has been created using heuristic methods by Coffee Cafe in order to get the most optimal routes for their dispatches.
All the dispatches takes place from city warehouse. The city warehouse caters to 174 café's across Bangalore. Three trucks cater to these 174 café's over a six-day period every week from Monday to Saturday; the cycle repeats every week. This basically means every café is relieved of new stock once every week. The model that is followed is direct and simple.

The summary of the initial delivery schedule is as follows. Through observation, an average unloading time of eleven minutes has been taken for each cafe.

TRUCK DETAILS and CARTON SPECIFICATIONS

The truck is a 4x2 Haulage truck, comes in chassis with built cabin & body and is used for carrying market loads with the following specifications:

- Loading Capacity : 12.5 Tonnes
- Payload : 8355 Kgs
- Max Speed : 90 Km/h
- Body Dimensions : 4828 x 2268 x 1800 mm
- The volumetric capacity of the truck is 696 cubic feet.

Note: With proper maintenance and working conditions, the truck operates an average of seven kilometers per liter of diesel.

Coffee Cafe makes use of standard size cartons for cafe dispatches. The dimensions of a typical carton are – 3.15ft x 1.85ft x 1.45ft.The volumetric capacity of a particular carton is 8.45 cubic feet and they should make optimum use of the truck capacity.

LEVEL OF STACKING

At its maximum limit, each truck can hold eighty such boxes. Length-wise, it can accommodate five rows of boxes. Width-wise, the truck can accommodate four rows of boxes. And height-wise, there can be four levels of stacking, thus bringing the total capacity to eighty boxes. This arrangement leaves the maximum available capacity at 676 cubic feet.

Truck	Distance/week (Km)
1	**295.89**
2	**217.14**
3	**330.22**

Table. 1: Distance Covered per truck / week-Existing

\Day	Distance covered (3trucks)
Monday	209.055
Tuesday	201.39
Wednesday	113.4
Thursday	85.995
Friday	157.29
Saturday	76.125

Table 2: Distance covered day-wise

In the existing model the total distance covered by the 3 trucks is 3373kms per month. Also the number of trips made by the 3 trucks per month from the city warehouse is 72.

III. TECHNIQUES USED

Given a list of cafes and the distances between each cafe, the Travelling Salesman Problem (TSP) finds the shortest possible route that visits each cafe exactly once and returns to the origin which in this case is the warehouse.

Symmetric and Asymmetric TSP

In the symmetric TSP, the distance between two café's is the same in each opposite direction. This symmetry halves the number of possible solutions. In the asymmetric TSP, paths may not exist in both directions or the distances might be different. Traffic collisions, one-way streets, and airfares for cities with different departure and arrival fees are examples of how this symmetry could break down. We have used an asymmetric model to solve the problem.

ALGORITHM USED IN SOLVING THE PROBLEM:

- Is used to solve problems for which a sequence of objects is to be selected from a set such that the sequence satisfies some constraint
- Traverses the state space using a depth-first search with pruning
- Performs a depth-first traversal of a tree
- Continues until it reaches a node that is non-viable or non-promising
- Prunes the sub tree rooted at this node and continues the depth-first traversal of the tree.

Example: N-Queens Problem

- Given an N x N sized chess board
- Objective: Place N queens on the board so that no queens are in danger.

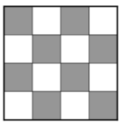

Fig. 1: N-Queens Problem

One option would be to generate a tree of every possible board layout. This would be an expensive way to find a solution.

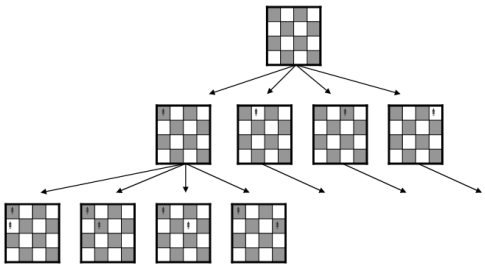

Fig. 2: Tree structure for possible board layout

- Backtracking prunes entire sub trees if their root node is not a viable solution
- The algorithm will "backtrack" up the tree to search for other possible solutions.

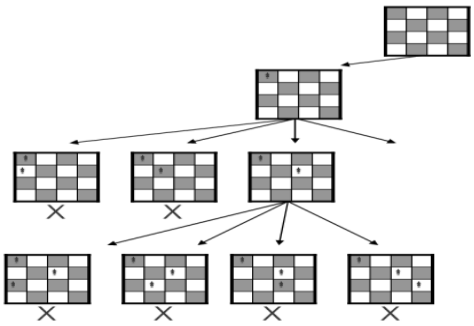

Fig. 3: Branch & Bound method

EFFICIENCY OF BACKTRACKING

- This given a significant advantage over an exhaustive search of the tree for the average problem
- Worst case: Algorithm tries every path, traversing the entire search space as in an exhaustive search.

BRANCH AND BOUND

- Where backtracking uses a depth-first search with pruning, the branch and bound algorithm uses a breadth-first search with pruning
- Branch and bound uses a queue as an auxiliary data structure.

BRANCH AND BOUND ALGORITHM

- Starting by considering the root node and applying a lower-bounding and upper-bounding procedure to it
- If the bounds match, then an optimal solution has been found and the algorithm is finished
- If they do not match, then algorithm runs on the child nodes.

EFFICIENCY OF BRANCH AND BOUND

- In many types of problems, branch and bound is faster than branching, due to the use of a breadth-first search instead of a depth-first search
- The worst case scenario is the same, as it will still visit every node in the tree.

IV. PROPOSED MODEL

The main aim of the proposed model is to provide a delivery network which has been designed optimally so that it minimizes the distance travelled. Also, the number of trips which the trucks take in a delivery cycle should be reduced.

The following steps were taken to set-up a new distribution network:

- Firstly, a list of all the cafes which are to be served in the model was created.
- Using the Google Maps navigation application, the distances of all the cafes from the two warehouses were established.
- Based on distances/travel time/priority, the cafes were distributed between the two warehouses i.e. Mother ware house and City warehouse.

Cafe's Operating under	Mother warehouse	City warehouse
	35	134

Table 3: Division of Warehouses

Once the café's were identified the next step was to collect the details of the dispatch data for each warehouse. Currently the warehouse maintains written logs regarding dispatch of cartons to a particular cafe. These are twice checked before dispatch by the Outward In-charge at the warehouse. The corresponding quantity of item-wise dispatch is maintained in the company's ERP software.

Based on the available data, a mean of the dispatch quantity was taken,to set a mark for segregation of the cafés segregation of the cafes in to two groups for each warehouse was done as explained below

- The first group contained cafe's which had an average weekly dispatch of 51 cubic feet material or less and these were considered as Low Demand cafes.
- The other group contained of cafe's which had an average weekly dispatch of 59 cubic feet material or less and these were considered as High Demand Cafes.

	Low Demand Cafe's(nos)	High Demand Cafe's(nos)
Mother Warehouse	18	17
City Warehouse	90	44
Total	108	61

Table 4: Distribution of Cafe's based on Categories

The warehouse does not deal with any perishable items hence all the materials have a considerably long shelf life. Considering the above facts and after deliberations it was decided that all the Low Demand Café's were to have a bi-weekly dispatch cycle instead of a weekly cycle as per the current model. This meant that they were to be replenished only once in two weeks which further saved cost(procurement) and holding inventory(space & cost) for the management.

The next task was to form a delivery schedule for the café's. For this purpose, we made use of Google Maps navigation application. However, there was a constraint on the capacity of the truck. So, the clustering technique was used. The café's in a particular area were manually grouped by using the application such that they did not overshoot the truck capacity. All the café's were divided into 18 different groups such that none of the groups crossed the upper limit on the truck capacity.

Once this was done, the distance matrices were formed as required in the TSP. Distances were taken for all the locations from one another and were put into the matrix. The solutions of the matrices were the optimum routes for the respective groups. In all 18 routes were attained.

After obtaining the routes, the following allotments were carried out as represented below:

Days of Week	Type of Cafe's served
Monday, Tuesday & Wednesday	High Demand Cafes to be served from both mother warehouse & city warehouse.
Thursday, Friday & Saturday	Low Demand Cafes to be served from both mother warehouse & city warehouse.

Table 5: Types of café served details

The new model has the following specifications:

- Total distance covered by all the trucks/month is:2204.8kms.
- The number of trips from the warehouse(s)/month: 50(11 Low Demand Routes which will be followed only once in two weeks which makes up 22 trips per month. Along with 7 High Demand Routes which will be followed every week, it gives 28 trips per month. The total comes to 50 trips per month)

V. RESULT

A comparison between the Existing Model and the Proposed Model is shown in a tabular form.

S.No.	Data/month	Existing model	Proposed model
1	Total distance (in kms/month)	3373	2204.8
2	No. of trips	72	50
Total distance saved/month(3373-2204.8)=1168.2kms			
Number of trips reduced /month(72-50)=22			
Total cost saved/month: Rs.8844.64/month*			

Table 6: Comparison and Savings

As can be seen the proposed model has considerably brought down the total distance travelled per month by all the three trucks using the TSP. The distance savings come to 1168.2 kms/ month.

Secondly, by grouping the outlets into low and high demand café's based on the dispatch data, the proposed model has brought down the number of trips taken by the three trucks from 72 per month to 50.

VI. CONCLUSION

This work was carried out with an aim to reduce the distance travelled and the number of trips taken by the delivery trucks. With the help of the TSP, we have not only reduced travelled distance but have also come out with a delivery network which is optimum, technically sound, and scientifically designed. Also, cost savings to the tune of 35 % in the transportation department is very useful for the company in improving their profits and forming an efficient supply chain. An optimum delivery network also saves the time spent in transportation, along with this, the division of the café's into high and low demand categories have helped reduce the number of trips taken by the trucks as well as transportation cost.

It has also reduced the warehouse activity level and the manpower requirements. Further, the trucks are readily available if an emergency delivery needs to be done in case of shortage of material at a particular cafe or damage to the stock.

Overall, it means that the proposed model is now more efficient and feasible than the existing model. The project has succeeded in finding a solution to the initial problems. The company has implemented our proposal and has appreciated our work carried out at their warehouse.

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