



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 8, August 2023

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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# Optimization of the Distribution Network of Packaged Food Industry

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**ABSTRACT:** In today's globalized society, transportation contributes to our daily life in many different ways. To deliver competitive service and price, transportation today needs to be cost effective. This research has been conducted for a packaged food distribution center located at Bangalore. The total number of retailers is 550 to be covered over a period of 5 days. Currently, the sales universe for Monday, has 100 stores in Malleshwaram out of which, 50 stores are visited and their demands are met. The different constraints makes it difficult for the distributor to cover all the shops, hence this Vehicle Routing problem has been taken up to give a better solution.

The typical objective of routing and scheduling is to minimize cost by decreasing the total distance travelled and the total travel time of the vehicles. Depending on the problem type, the size of the problems and time available for solving, different solution methods can be applied. Here, the methodology used to achieve this objective is "Savings Matrix Method". Savings matrix method has been implemented to find the routes. Two routes have been identified one with 49 retailers and other with 51 retailers. Initially total distance travelled was 43 kms for visiting only 50 retailers and after redesigning the network, 100 retailers were visited by travelling only 52.66 kms.

**KEYWORDS:** Travelling Salesman Problem, Vehicle Routing Problem, Savings Matrix Method, Distribution Network Optimization, TSP

## I. INTRODUCTION

In mathematics and economics, transportation theory is a name given to the study of optimal transportation and allocation of resources. The problem was formalized by the French mathematician Gaspard Monge in 1781.

In the 1920s A.N. Tolstoi was one of the first to study the transportation problem mathematically. In 1930, in the collection Transportation Planning Volume I for the National Commissariat of Transportation of the Soviet Union, he published a paper "Methods of Finding the Minimal Kilo meter in Cargo-transportation in space".

Over centuries transportation problems have been in every business enterprise because every enterprise in some or the other way needs or delivers some products and services. Various methods have been developed over centuries to master these problems however digital world has been a great help here where there isn't any requirement of manual computation as well as no risks of human made mistakes in computation.

The transportation problem is a distribution-type problem, the main goal of which is to decide how to transfer goods from various sending locations to various receiving locations or from one location to various locations with minimal costs or maximum profit. As long as the number of origins and destinations is low, this is a relatively easy decision. But as the numbers grow, this becomes a complicated linear programming problem to find the optimal solution.

## METHODS TO FIND OPTIMAL SOLUTION: ASSIGNMENT METHOD

The assignment problem is one of the fundamental combinatorial optimization problems in the branch of optimization or operations research in mathematics. It consists of finding a maximum weight matching (or minimum weight perfect matching) in a weighted bipartite graph. In its most general form, the problem is as follows:

The problem instance has a number of agents and a number of tasks. Any agent can be assigned to perform any task, incurring some cost that may vary depending on the agent-task assignment. It is required to perform all tasks by assigning exactly one agent to each task and exactly one task to each agent in such a way that the total cost of the assignment is minimized.

## DIJKSTRA'S ALGORITHM

Dijkstra's algorithm is invented by Dutch computer scientist Edsger Dijkstra in 1956 and published in 1959, is a graph based searching algorithm that solves the single source shortest path problem. It is applied on positive weights graphs.

#### SAVINGS MATRIX METHOD

Saving matrix (matrix savings) is one method that can be used to assist in solving the problem of determining the delivery route. In this method the matrix is the saving procedure used to sort consumers, there are nearest neighbor, farthest insert, and nearest insert to insert the customers.

However, this method has constraint of one single node point. There should be only single point of supplier having single truck to be delivered to different node points.

This method is simple to implement and can be used to assign customers to vehicles even when delivery time windows or other constraints exist. The major steps in the savings matrix method are:

1. Identify the distance matrix.
2. Identify the savings matrix.
3. Assign customers to vehicles or routes.
4. Sequence customers within routes.

#### ROUTE SEQUENCING PROCEDURES

Route sequencing procedures can be used to obtain an initial trip for each vehicle. The initial trip can then be improved using the route improvement procedures.

##### Travelling Salesman Problem

The travelling salesman problem (TSP) asks the following question: "Given a list of retailers and the distances between each pair of retailers, what is the shortest possible route that visits each retailer and returns to the origin?" It is an NP-hard problem in combinatorial optimization, important in operations research and theoretical computer science.

##### Farthest Insert

Given a vehicle trip including the Distribution Center (DC) for each remaining customer, find the minimum increase in length for this customer to be inserted from all the potential points in the trip that the customer could be inserted. Then choose to actually insert the customer with the largest minimum increase to obtain a new trip. This step is referred to as a farthest insert because the customer farthest from the current trip is inserted. The process is continued until all remaining customers to be visited by the vehicle are included in a trip.

##### Nearest Insert

Given a vehicle trip including the DC for each remaining customer, find the minimum increase in length for this customer to be inserted from all the potential points in the trip that the customer could be inserted. Insert the customer with the smallest minimum increase to obtain a new trip. This step is referred to as a nearest insert because the customer closest to the current trip is inserted. The process is continued until all remaining customers the vehicle will visit are included in a trip.

##### Nearest Neighbour

Starting at the DC, this procedure adds the closest customer to extend the trip. At each step, the trip is built by adding the customer closest to the point last visited by the vehicle until all customers have been visited.

The saving matrix method is one method that is easy to apply for complex distribution problems quickly. The advantage of this method lies in its ease of modification. If there are obstacles such as vehicle capacity, number of vehicles, delivery time or other constraints, it can provide a quick and practical solution even though the results do not guarantee optimal solutions. [1]

## II. LITERATURE SURVEY

Dantzig and Ramser 1959 described the goal of Vehicle Routing Problem (VRP) to design route(s) for vehicles stationed at a depot(s) in order to deliver the goods to the customers in minimum time, distance and cost. Several variants and specializations of the vehicle routing problem exist. The basic variation of the classical VRP is Capacitated Vehicle Routing Problem (CVRP). In CVRP, the demand is not variable and is known in advance. There is also a capacity constraint on the vehicles. The objective of CVRP is to minimize the cost of transportation by varying other functions such as length of routes, number of vehicles or travel time. [2]

One of the earliest deterministic solutions to Travelling Salesman Problem (TSP) was provided by Dantzig et al., in which linear programming (LP) relaxation is used to solve the integer formulation by adding suitably chosen linear inequality to the list of constraints continuously. [3]

The branch and bound technique based algorithm published [4] was able to successfully increase the size of the problem solvable without using any problem specific methods. The algorithm branches into the set of all possible tours while calculating the lower bound on the length of the tour for each subset. Eventually it finds a single tour in a subset whose length is less than or equal to some lower bound for every tour. The algorithm however grows exponentially in time with the input, but it is able to calculate the TSP for 40 cities with appreciable average time consumption as displayed by the authors.

The Lin-Kernighan heuristic is generally considered to be one of the most effective methods for generating optimal or near-optimal solutions for the symmetric TSP. The heuristic grows by a relation of  $n^2$  with time as shown in the paper by W. Kernighan. [5]

Little attention has been paid to physical distribution function in channels research within the marketing literature. This topic has received more emphasis in other literatures, such as in operations management, logistics, transportation, purchasing and information technology, with a general focus on how product orders can be efficiently and effectively processed, and then delivered to channel members and end-customers. Among the main areas of interest have been inventory management, the number placement, and design of warehouses or distribution centers, the use of technology to aide in processing orders, delivery options to customers, and customer payment methods. [6]

Though the field of marketing, in general, has adopted a strategic perspective, one particular area, distribution channels, has been relatively slow to embrace this perspective. The importance of marketing channel strategy decisions is highlighted by

- 1) Their inherent long-term consequences and
- 2) The constraints and opportunities that they represent. [7]

The development of relationships in a marketing channel often takes a great deal of time and effort. Therefore, any decisions made concerning these relations take on added strategic importance. Given this, the incorporation of strategic management theory is very relevant to the study of distribution channels. [8]

Nowadays, marketing channels which provide the institutional structure that connects firms to the markets they serve have not escaped the global environment. On the contrary, in today's world, marketing channel structure and strategy must be formulated in the context of globalization. [9]

Not only do today's channel managers need to think globally, but they must also act locally in terms of providing the appropriate array of channels desired by heterogeneous markets all over the world. [10]

### III. PROCESS DESCRIPTION

Figure 1 gives the distribution network of the company. The company directly accepts the invoice from the Super stockist when raised, thus eliminating the CFA component for faster service.

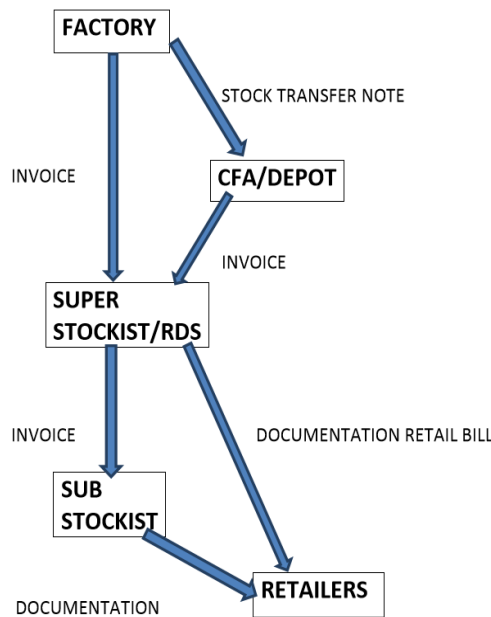


Fig 1. Flow chart depicting the flow of product

The next step involves two possibilities wherein the Sub stockist may raise an invoice to the Super Stockist and may deliver the goods to the Retailers via a Documentation Retail Bill. Another possibility being the Super Stockist directly producing the required goods to the Retailers through a Documentation Retail Bill.

Table 1 gives the sales universe of the company for 6 days. Everyday a different area is tackled for acquiring sales in the city of Bengaluru. The areas for each day are mentioned in the first column, the second column gives the sales universe of that particular area, the third column indicates the shops approached by the salesman on the day, and the fourth column gives the shops from which orders are received for the various products.

Table 1: Sales universe details

SL NO	DAY	SALES UNIVERSE	SHOPS PRESENT	SHOPS VISITED	ORDERS RECEIVED
1	MONDAY	MALLESHWARAM, PALACE GUTAHALLI	100	50	40
2	TUESDAY	SESHADRIPURAM, VASANTH NAGAR	100	50	30
3	WEDNESDAY	SUBRAMANYANAGAR, GAYATHRINAGAR	80	55	35
4	THURSDAY	RAJAJINAGAR	75	45	28
5	FRIDAY	PRAKASH NAGAR, L N PURA	120	60	40
6	SATURDAY	SRIRAMPURA	75	50	35

The sales universe or shops available to sell items at on an average is around 100 at a given region, but on an average the company is only able to visit approximately 50% of the stores in that region and out of this 50% only about 80% of the shops purchase items. In one week one particular region is visited only once. So the main problem is reachability, this means that the company is not able to sell more because the company is not able to reach all the potential customers.

#### IV. PROBLEM ANALYSIS

In this research, the sales that happen on Monday done in the Malleshwaram region are considered because it is the first day of the week and once this has been optimized the method can be implemented for the other days of the week. Here there are 100 retailers and the distributor currently visits only 50 stores. The main objective is to cover more stores and in turn generate more sales and this can be considered as a transportation problem and there are many methods that can be used to find the optimal solution.



DATA COLLECTION

The distribution center is located in Rajajinagar. Data was collected (Table 2) for 100 retailers about:

- The location of 100 retailers.
- The distance between each retailer and the distribution center.
- The weekly demands of retailers.

Table 2: Data about retailers location, distance from distribution center and weekly demand

Shop number	Distance from centre (km)	Demand in cartons	Shop number	Distance from centre (km)	Demand in cartons	Shop number	Distance from centre (km)	Demand in cartons
R1	5.4	3	R35	4.7	2	R68	2.9	2
R2	3.9	3	R36	2	1	R69	3.6	3
R3	4	4	R37	3.1	1	R70	3.3	2
R4	4.1	2	R38	4.3	3	R71	2.8	5
R5	4.8	2	R39	3.9	4	R72	3.1	2
R6	4.6	3	R40	4.7	4	R73	3.3	4
R7	3.7	5	R41	3.8	5	R74	6.4	3
R8	4	3	R42	4.2	2	R75	4.5	3
R9	6.6	3	R43	3.2	2	R76	2.3	1
R10	5.8	4	R44	4.5	3	R77	4.5	4
R11	4.9	2	R45	4.9	4	R78	4.7	3
R12	4.0	4	R46	4.8	3	R79	5.8	5
R13	3.6	5	R47	2.9	3	R80	6.5	2
R14	3.8	3	R48	3.6	1	R81	2.4	2
R15	4.2	2	R49	5.5	2	R82	4.2	4
R16	2.9	4	R50	6	5	R83	3.7	4
R17	3.4	2	R51	4.1	2	R84	2.1	3
R18	3.8	2	R52	3.8	1	R85	2.9	4
R19	4.1	4	R53	5.2	3	R86	4.9	4
R20	4.8	3	R54	2.9	2	R87	5.8	1
R21	4.2	4	R55	3.4	2	R88	3.3	3
R22	3.7	2	R56	3	1	R89	6.8	4
R23	3.8	1	R57	4.5	3	R90	3.8	5
R24	3.5	2	R58	4.6	3	R91	4	3
R25	4.3	6	R59	4.7	5	R92	4.2	4
R26	4	3	R60	5.1	2	R93	4.6	4
R27	4.1	1	R61	4.9	4	R94	6	2
R28	3.8	3	R62	4	4	R95	4.7	3
R29	3.1	2	R63	5.1	2	R96	4.9	3
R30	4.5	3	R64	3.1	4	R97	3.1	2
R31	3.7	2	R65	3.7	3	R98	5.1	4
R32	4.2	4	R66	5.9	3	R99	2.8	2
R33	4.3	4	R67	5.1	4	R100	6.1	3
R34	2.1	3					<b>Total</b>	<b>299</b>



The present route used for distributing the products is shown below.

DC → R16 → R1 → R20 → R3 → R4 → R7 → R5 → R8 → R6 → R11 → R15 → R12 → R18 → R17 → R10 → R45 → R19 → R26 → R56 → R30 → R47 → R2 → R52 → R93 → R9 → R83 → R13 → R29 → R27 → R24 → R43 → R14 → R28 → R34 → R39 → R23 → R36 → R31 → R65 → R57 → R51 → R75 → R60 → R62 → R63 → R73 → R78 → R69 → R55 → R86 → DC

Total Distance travelled = 43 Kms

Total Retailers Covered = 50

**METHODOLOGY USED TO SOLVE THE PROBLEM**

The problem witnessed was that on an average only 50% of the retailers were visited on a particular day. It was felt that the distribution network has to be redesigned in order to reduce the total distance travelled and cost incurred. To find the best route the Savings Matrix Method has been applied.

**Table 3:** Truncated Distance Matrix (all values are in Kms.)

	DC	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
DC	0	5.4	3.9	4	4.1	4.8	4.6	3.7	4	6.6	5.8
R1	5.4	0	4.8	4.7	3.6	4.6	5	3.7	3.9	3.7	5.1
R2	3.9	4.8	0	6.6	0.55	0.6	0.85	1.9	1.3	4.6	1.2
R3	4	4.7	6.6	0	0.8	0.9	1.6	0.65	0.09	0.9	0.3
R4	4.1	3.6	0.55	0.8	0	1.4	2.3	0.5	0.55	0.35	1.7
R5	4.8	4.6	0.6	0.9	1.4	0	2.8	0.75	1.1	2.2	2.8
R6	4.6	5	0.85	1.6	2.3	2.8	0	1.3	0.8	2.1	1.8
R7	3.7	3.7	1.9	0.65	0.5	0.75	1.3	0	1	0.15	2.1
R8	4	3.9	1.3	0.09	0.55	1.1	0.8	1	0	1.1	1
R9	6.6	3.7	4.6	0.9	0.35	2.2	2.1	0.15	1.1	0	3.1
R10	5.8	5.1	1.2	0.3	1.7	2.8	1.8	2.1	1	3.1	0

**SAVINGS MATRIX METHOD**

The steps involved in Savings Matrix Method are shown below:

**STEP 1: Identification of Distance Matrix (Table 3)**

Google Maps Application was used to determine the distance between every retailer and keyed it into the matrix. Google maps was used so that the best route which has the least distance to be covered and takes the least amount of time can be obtained.

**STEP 2: Identification of Savings Matrix (Table 4)**

The savings matrix represents the savings that accrue on consolidating two customers on a single truck. Savings may be evaluated in terms of distance, time, or money. The manager at the Peapod DC constructs the savings matrix in terms of distance. A trip is identified as the sequence of locations a vehicle visits. The trip DC →Cust x → DC starts at the DC, visits customer x, and returns to the DC. The savings S(x,y) is the distance saved if the trips DC →Cust x → DC and DC →Cust y → DC are combined to a single trip, DC →Cust x →Cust y → DC. These savings can be calculated by the following formula:

$$S(x,y) = \text{Dist}(\text{DC}, x) + \text{Dist}(\text{DC}, y) - \text{Dist}(x, y).$$



**Table 4:** Truncated Savings Matrix (all values are in Kms.)

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	0	4.5	4.7	5.9	5.6	5	5.4	5.5	8.3	6.1
R2	4.5	0	1.3	7.45	8.1	7.65	5.7	6.6	5.9	8.5
R3	4.7	1.3	0	7.3	7.9	7	7.05	7.91	9.7	9.5
R4	5.9	7.45	7.3	0	7.5	6.4	7.3	7.55	10.35	8.2
R5	5.6	8.1	7.9	7.5	0	6.6	7.75	7.7	9.2	7.8
R6	5	7.65	7	6.4	6.6	0	7	7.8	9.1	8.6
R7	5.4	5.7	7.05	7.3	7.75	7	0	6.7	10.15	7.4
R8	5.5	6.6	7.91	7.55	7.7	7.8	6.7	0	9.5	8.8
R9	8.3	5.9	9.7	10.35	9.2	9.1	10.15	9.5	0	9.3
R10	6.1	8.5	9.5	8.2	7.8	8.6	7.4	8.8	9.3	0

Sample Calculation:

For,

$$S(1,2) = \text{Dist}(DC,1) + \text{Dist}(DC,2) - \text{Dist}(1,2)$$

$$= 5.4 + 3.9 - 4.8$$

$$= 4.5$$

$$S(4,9) = \text{Dist}(DC,4) + \text{Dist}(DC,9) - \text{Dist}(4,9)$$

$$= 4.1 + 6.6 - 0.35$$

$$= 10.35$$

STEP 3: Identification of possible routes for delivery (Table 5 and Table 6)

The criteria is to get maximum savings hence from the savings matrix the highest savings is identified then the two retailers are combined and then the next highest savings is identified and combined to the previously found retailers the process is repeated until the demand is equal to or lesser than the maximum capacity of the truck being used. In this case the maximum limit of capacity is 150 cartons.

The highest savings in the Savings Matrix is 12.7 and is between retailers 9 and 89, after ignoring retailers 9 and 89 the next highest savings is 11.3 between retailers 50 and 74, this procedure is followed to get the two routes keeping the total demand lesser or equal to the total capacity.

**Table 5:** First Optimal route identified

Retailers	Demand in Cartons	Retailers	Demand in Cartons	Retailers	Demand in Cartons	Retailers	Demand in Cartons
R9	3	R13	5	R52	1	R64	4
R89	4	R4	2	R11	2	R23	1
R50	5	R63	2	R73	4	R31	2
R74	3	R94	2	R44	3	R65	3
R10	4	R60	2	R70	2	R40	4
R80	2	R87	1	R5	2	R20	3
R96	3	R66	3	R6	3	R34	3
R100	3	R67	4	R53	3	R39	4
R45	4	R86	4	R16	4	R82	4
R88	3	R79	5	R3	4	R71	5
R93	4	R1	3	R81	2	R48	1
R49	2	R61	4	R98	4	R36	1
						R69	3
						<b>Total</b>	<b>149</b>





Table 6: Second Optimal Route Identified

Retailers	Demand in Cartons	Retailers	Demand in Cartons	Retailers	Demand in Cartons	Retailers	Demand in Cartons
R25	6	R8	3	R57	3	R37	1
R46	3	R35	2	R22	2	R28	3
R21	4	R33	4	R30	3	R62	4
R27	1	R97	2	R92	4	R14	3
R72	2	R75	3	R84	3	R54	2
R42	2	R19	4	R18	2	R56	1
R43	2	R15	2	R26	3	R91	3
R77	4	R12	4	R59	5	R58	3
R78	3	R2	3	R32	4	R47	3
R90	5	R17	2	R41	5	R24	2
R83	4	R76	1	R85	4	R68	2
R99	2	R38	3	R29	2	R55	2
R95	3	R51	2	R7	5	<b>Total</b>	<b>150</b>

STEP 4: Sequencing the routes

Two routes were identified using the savings matrix to cover all 100 retailers in Malleshwaram area. To find the most efficient sequence Travelling Salesman Problem software was used.

The optimal sequence within each route is shown below:

**ROUTE 1:**

DC → R34 → R80 → R73 → R44 → R66 → R67 → R69 → R88 → R13 → R5 → R36 → R23 → R81 → R10 → R82 → R63 → R98 → R86 → R79 → R6 → R53 → R61 → R93 → R52 → R71 → R64 → R3 → R48 → R70 → R40 → R1 → R89 → R60 → R87 → R50 → R96 → R100 → R16 → R94 → R49 → R31 → R65 → R9 → R45 → R4 → R74 → R20 → R11 → R39 → DC

TOTAL DISTANCE TRAVELLED = 16.065 km

**ROUTE 2:**

DC → R92 → R51 → R75 → R18 → R91 → R55 → R97 → R22 → R62 → R14 → R42 → R21 → R8 → R35 → R29 → R27 → R57 → R24 → R43 → R12 → R15 → R95 → R54 → R99 → R76 → R19 → R56 → R7 → R26 → R58 → R25 → R90 → R2 → R47 → R17 → R83 → R68 → R77 → R72 → R78 → R38 → R85 → R41 → R32 → R46 → R33 → R37 → R28 → R59 → R30 → R84 → DC

TOTAL DISTANCE TRAVELLED = 36.59 km

V. RESULTS

After analysis of Present Network and Proposed Network for distribution of spice products the following results are obtained that helps to save time, money and improve the sales (Table 7). Initially total distance travelled was 43 kms for visiting only 50 retailers and after redesigning the network, 100 retailers were visited and the total distance travelled is 52.655 kms. Initially total cost incurred for visiting 50 retailers was Rs.1,030 and after redesigning the network, the cost incurred is Rs.1,843 for visiting 100 retailers.



Table 7: Comparison of Present and Proposed distribution Network.

Particulars	Present Network	Proposed Network
Retailers visited (No.)	50	100
Distance travelled (km)	43	52.655
Cost Incurred (Rs)	1,030	1,843

VI. CONCLUSION

In the beginning it was observed that on Mondays the salesman would visit 50 out of 100 retailers in Malleshwaram area for the distribution of spice products. The distribution network was completely redesigned in order to visit all 100 retailers. Using the savings matrix method, two routes were identified and optimization within the routes was performed using a TSP software (Data Solver) and a network where all 100 retailers are visited was found. After redesigning the entire network, it was found that all 100 retailers could be visited by travelling only 52.655 Kms. and incurring a cost of Rs. 1,843. The redesigning of network could be carried out similarly for other week days.

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