CHAPTER 14: METAHEURISTICS

14.1-1.

(a)

Tours	Distance	Tours	Distance
1-2-3-4-5-1	34	1-3-2-4-5-1	32
1-2-3-5-4-1	34	1-3-2-5-4-1	26
1-2-4-3-5-1	36	1-3-4-2-5-1	28
1-2-4-5-3-1	31	1-3-5-2-4-1	28
1-2-5-3-4-1	30	1-4-2-3-5-1	37
1-2-5-4-3-1	25	1-4-3-2-5-1	31

Optimal Solution: 1-2-5-4-3-1 (or the reverse 1-3-4-5-2-1)

(b) Start with the initial trial solution 1-2-3-4-5-1. There are three possible sub-tour reversals that improve upon this solution.

	1-2-3-4-5-1	Distance = 34
Reverse 2-3	1-3-2-4-5-1	Distance = 32
Reverse 2-3-4	1-4-3-2-5-1	Distance = 31
Reverse 3-4-5	1-2-5-4-3-1	Distance = 25

Choose 1-2-5-4-3-1 as the next trial solution. There is no sub-tour reversal that improves upon this solution. The tour 1-2-5-4-3-1 is optimal.

(c) Start with the initial trial solution 1-2-4-3-5-1. There are four possible sub-tour reversals that improve upon this solution.

	1-2-4-3-5-1	Distance = 36
Reverse 4-3	1-2-3-4-5-1	Distance = 34
Reverse 3-5	1-2-4-5-3-1	Distance = 31
Reverse 2-4-3	1-3-4-2-5-1	Distance = 28
Reverse 4-3-5	1-2-5-3-4-1	Distance = 30

Choose 1-3-4-2-5-1 as the next trial solution. There is only one possible sub-tour reversal that improves upon this solution.

	1-3-4-2-5-1	Distance = 28
Reverse 2-5	1-3-4-5-2-1	Distance = 25

Choose 1-3-4-5-2-1 as the next trial solution. There is no sub-tour reversal that improves upon this. The solution 1-3-4-5-2-1 is optimal.

(d) Start with the initial trial solution 1-4-2-3-5-1. There are five possible sub-tour reversals that improve upon this solution.

	1-4-2-3-5-1	Distance = 37
Reverse 2-4	1-2-4-3-5-1	Distance = 36
Reverse 2-3	1-4-3-2-5-1	Distance = 31
Reverse 3-5	1-4-2-5-3-1	Distance = 28
Reverse 4-2-3	1-3-2-4-5-1	Distance = 32
reverse 2-3-5	1-4-5-3-2-1	Distance = 34

Choose 1-4-2-5-3-1 as the next trial solution. There is only one possible sub-tour reversal that improves upon this solution.

	1-4-2-5-3-1	Distance = 28
Reverse 2-5	1-4-5-2-3-1	Distance = 26

Choose 1-4-5-2-3-1 as the next trial solution. There is one possible sub-tour reversal that improves upon this.

	1-4-5-2-3-1	Distance = 26
Reverse 4-5-2	1-2-5-4-3-1	Distance = 25

Choose 1-2-5-4-3-1 as the next trial solution. There is no sub-tour reversal that improves upon this. The solution 1-2-5-4-3-1 is optimal.

14.1-2.

(a) If the second reversal were chosen, the next trial solution would be 1-2-3-5-4-6-7-1 and there is no sub-tour reversal that gives an improvement.

(b) Start with the initial trial solution 1-2-4-5-6-7-3-1. There are two possible sub-tour reversals that improve upon this solution.

	1-2-4-5-6-7-3-1	Distance = 69
Reverse 5-6	1-2-4-6-5-7-3-1	Distance = 66
Reverse 2-4-5-6-7	1-7-6-5-4-2-3-1	Distance = 68

Choose 1-2-4-6-5-7-3-1 as the next trial solution. There is only one possible sub-tour reversal that improves upon this.

	1-2-4-6-5-7-3-1	Distance = 66
Reverse 5-7	1-2-4-6-7-5-3-1	Distance = 63

Choose 1-2-4-6-7-5-3-1 as the next trial solution. This is an optimal solution.

14.1-3.

(a)

Tours	Distance	Tours	Distance
1-2-3-4-5-6-1	64	1-2-6-3-4-5-1	69
1-2-3-4-6-5-1	59	1-5-2-3-4-6-1	56
1-2-3-6-4-5-1	67	1-5-2-4-3-6-1	61
1-2-4-4-6-5-1	64	1-6-2-3-4-5-1	63
1-2-5-4-3-6-1	67	1-6-3-2-4-5-1	66

Optimal Solution: 1-5-2-3-4-6-1 (or the reverse 1-6-4-3-5-2-1)

(b) Start with the initial trial solution 1-2-3-4-5-6-1. There are two possible sub-tour reversals that improve upon this solution.

	1-2-3-4-5-6-1	Distance = 64
Reverse 5-6	1-2-3-4-6-5-1	Distance = 59
Reverse 2-3-4-5	1-5-4-3-2-6-1	Distance = 63

Choose 1-2-3-4-6-5-1 as the next trial solution. There is no sub-tour reversal that improves upon this solution.

(c) Start with the initial trial solution 1-2-5-4-3-6-1. There are two possible sub-tour reversals that improve upon this solution.

	1-2-5-4-3-6-1	Distance = 67
Reverse 2-5	1-5-2-4-3-6-1	Distance = 61
Reverse 5-4-3	1-2-3-4-5-6-1	Distance = 64

Choose 1-5-2-4-3-6-1 as the next trial solution. There is no sub-tour reversal that improves upon this solution.

14.2-1.

Sears logistics services (SLS) provides delivery with its fleet of over 1,000 vehicles. Sears product services (SPS) offers home service with its fleet of 12,500 vehicles and technicians. A customer who asks for delivery or home service is given a day and a time window based on customer preferences and working schedule in the region where the customer is located. In either case, the goal is to generate efficient routes for the vehicles and to provide customers with accurate and convenient time windows while minimizing the operational costs. Both problems are instances of vehicle routing problem with time windows (VRPTW). A basic VRPTW determines routes for M vehicles, each starting at the depot and returning to the depot after visiting a subset of customers in some order. Every customer is visited by exactly one vehicle. The capacity constraints of the vehicles and the time windows imposed by customers should be met. The objective is to minimize the total cost. The problems faced by SLS and SPS differ from the basic VRPTW in that they include additional constraints. For instance, in the case of SPS, technicians' skills need to be considered in assigning service orders to them. In both cases, there may be restrictions on total route times and travel times between any two locations. Hence, the

problem is a complex one and necessitates the use of a solution procedure that can provide good solutions in acceptable time.

To solve the problem, first an initial route is found for each vehicle, then unassigned stops are inserted into a route. This solution is improved using various local heuristic techniques. In order not to be stuck at local optima, the procedure is enhanced with tabu search technique. Once a stop in a route is relocated, the move is included in a tabu list and remains prohibited for a number of iterations unless the objective function value it offers exceeds the best value obtained up to that iteration.

Financial benefits of this study include $9 million in one-time savings and over $42 million in annual savings. The savings result from the reduction in travel times, mileage and routing times. Sears now offers more timely delivery of merchandise and home service, so more reliable customer service. The utilization of the fleets is improved. The routing process became faster and the facility, equipment and personnel costs related to routing decreased. Since the problem can be solved quickly, Sears can respond to disruptions and adjust its schedules more efficiently.

14.2-2.

Start with the initial trial solution with links AB, AC, AE, CD, which costs 232.

Iteration 1:

Add	Delete	Cost
BC	AB	138
	AC	246
BD	AB	56
	AC	164
	CD	268
DE	AC	152
	AE	240
	CD	256

Adding BD and deleting AB results in the lowest cost, so choose inserting links AC, AE, BD. CD. In fact, this is the optimal solution.