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MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

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TO WHOM IT MAY CONCERN

I hereby recommend that the Project entitled **MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION** prepared under my supervision by **Kishan Ojha (11700114036), Tonmoy Patra (11700114092), Pritam Bhattacharjee (11700114045), Harshit Dhawan (11700114032)** of B.Tech (8th Semester), may be accepted in partial fulfillment for the degree of **Bachelor of Technology in Computer Science & Engineering** under **Maulana Abul Kalam Azad University of Technology (MAKAUT)**.

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<u>CERTIFICATE OF APPROVAL</u>

The foregoing Project is hereby accepted as a credible study of an engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the project only for the purpose for which it is submitted.

FINAL EXAMINATION FOR   1. _____
EVALUATION OF PROJECT

                                    2._____

(Signature of Examiners)

ACKNOWLEDGEMENT

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Appendix-: *Program Source Code with adequate comments*

ABSTRACT

In this project, the main purpose is to determine optimal solution of capacitated vehicle routing problem using PSO algorithm. By optimal solution, it means deriving the route of the system so that it gives the maximum profit. Multiple and many objective optimization problems are alarming of high importance in recent scientific and the industrial world . Some of the practical optimization problems include flight rescheduling , shape optimization , mobile network design, and minimization of shooting failure probability in the weapon target assignment, etc.

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INTRODUCTION

Vehicle routing and scheduling are key components of the efficiency of modern supply chains, where quantities of goods and raw materials should be continuously exchanged in the seamless way possible. In its most common version, the vehicle routing problem (VRP) is used to plan the distribution of goods from a depot to a set of customers, and subject to some constraints, like vehicle restrictions and many other practical and industrial considerations. In other situations, products are exchanged between the customer, which leads to the pickup and delivery VRP. Vehicles can also be used to bring back the customers' goods to a central depot, or consolidation point, like in the waste collection problem. These practical routing problems deal with many real-world constraints and are often referred as rich VRP.

This work is a method for finding a solution of profit maximization of single depot Capacitated Vehicle Routing Problem with time deadline and minimum expense by using multi-objective optimization algorithm. In the capacitated vehicle routing problem, we are given a demand at each location, and each vehicle's maximum capacity. The constraint is to find an assignment of routes to vehicles so that the total demand of the locations on a vehicle's route does not exceed its capacity. The objective is to find the routes of vehicles under time deadline for maximizing the total profit and minimum expense, which is equal to the total revenue collected from the visited customers or cities, and to reduce the travelling expense. As multi objective profit maximization capacitated vehicle routing problem is a complex combinatorial optimization problem and it belongs to the NP-hard class, it is not possible to use exact methods of large instances for solving this type of vehicle routing problem. We have used PSO algorithm to solve the problem. We see that as we increase the number of iterations, PSO algorithm produces a much richer set of solutions. The problem has been solved by repeatedly updating the position and velocity of the particles.

Scheduling and routing problems are a subject of active research in the optimization community for a number of reasons. Firstly, they usually define challenging search problems, and are good for exercising computational techniques to their limits. Secondly, they are easily cast into formal specifications, and standardized data sets of varying complexity are often made for them. This permits well-defined problem instances to be shared amongst researchers, thus making for effective comparisons of methodologies used. Finally, they often have many practical real-world applications; the results are of genuine use to industry and others. Vehicle Routing Problems (VRPs) are well known combinatorial optimization problems arising in transportation logistics that usually involve scheduling in constrained environments.
Figure 1 shows an example of a routing solution for Capacitated Vehicle Routing problem (CVRP).

VRP is a typical NP-complete problem. However, exact techniques are applied only to small- scale problem FVRP is much more difficult than VRP, which is a special example of VRP under uncertainty. So intelligent methods have gained wide research, as was first presented in VRP, and Cheng and Gen used a genetic algorithm to solve the vehicle routing problem with fuzzy due-time. Moreover, such as Liu and Lai et al. modeled VRP with fuzzy travel times by fuzzy programming with a possibility measurement, and adopted the genetic algorithm to solve the model. Zheng and Liu researched the vehicle routing problem with fuzzy travel time, and presented a chance constrained program (CCP) model with credibility measurement, then integrated a fuzzy simulation and genetic algorithm (GA) etc, and achieved good results. Particle swarm optimization (PSO) algorithm is a parallel population-based computation technique originally developed by Kennedy and Eberhart, PSO can solve a variety of difficult optimization problems because of its advantages.

Although the PSO is developed for continuous optimization problem initially, there have been some reported works focused on discrete problems recently.
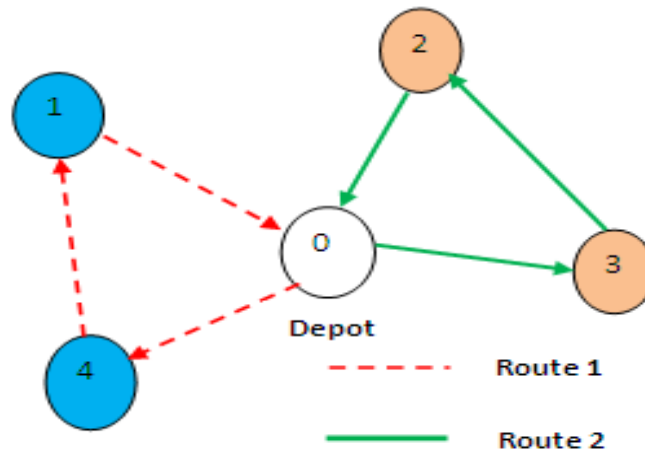
Fig1. Example of a Routing Solution for the CVRP

In transportation management, there is a requirement to provide goods and/or services from a supply point to various geographically dispersed points with significant economic implications. VRPs have received much attention in recent years due to their wide applicability and economic importance in determining efficient distribution strategies to reduce operational costs in distribution systems.

REVIEW OF LITERATURE

Objective is to solve the vehicle routing problem with fuzzy demands (FVRP) ,in FVRP, a fuzzy chance constrained program model is designed, based on fuzzy credibility theory. Firstly construct a suitable mapping between problem solution and PSO particle, and adopted appropriate procedure in the method.[1] Here, a new hybrid algorithmic approach based on discrete Particle Swarm Optimization (PSO) and optimal splitting procedure for solving one of the most popular supply chain management problems, the Vehicle Routing Problem (VRP). The VRP is a well known NP hard problem in which a vehicle with finite capacity leaves from the depot with full load and has to serve a set of customers whose demands are known only when the vehicle arrives to them. Experiment results show that the proposed algorithm is an efficient algorithm in solving VRP.[2]

VRP can be used to model many core problems arising in production and daily life practice, e.g. logistics and public transit. Searching for good solutions to these problems is very important, because it can provide decision-makers to utilize the existing fleet in the most cost-effective way to meet customer demands.[3]

A multi objective dynamic vehicle routing problem (M-DVRP) has been identified and a time seed based solution using particle swarm optimization (TS-PSO) for M-DVRP has been proposed. M-DVRP considers five objectives, namely, geographical ranking of the request, customer ranking, service time, expected reachability time, and satisfaction level of the customers. The multi objective function of M-VRP has four components, namely, number of vehicles, expected reachability time, and profit and satisfaction level. Three constraints of the objective function are vehicle, capacity, and reachability. In TS-PSO, first of all, the problem is partitioned into smaller size DVRPs. Secondly, the time horizon of each smaller size DVRP is divided into time seeds and the problem is solved in each time seed using particle swarm optimization.[4]

Multiple and many objective optimization problems are alarming of high importance in recent scientific and the industrial world . Some of the practical optimization problems include flight rescheduling , shape optimization , mobile network design, and minimization of shooting failure probability in the weapon target assignment, etc. In practice, the number of objectives in a multiple optimization problem are restricted with ≤3. However, numbers of objectives are at least 4 in the case of many objective optimization.[5]

Optimization is a method of finding the optimum solution i.e. finding the maximum or minimum of a given objectives, subjected to various constraints. In the literature, various advanced optimization techniques are available out of which particle swarm optimization is one of the advanced optimization technique. Particle swarm optimization (PSO) is an efficient optimization method. Like other algorithm PSO is also population based algorithm. The PSO is inspired by the metaphor of social interaction observed between fishes or birds. In a PSO algorithm, each particle is a candidate solution and each particle "flies" through the search space, depending on two important factors; the best position the current particle have found so far and the global best position identified from the entire population. PSO has been used in many fields such as in aerospace design, manufacturing, heat transfer and automobile. Results obtained by particle swarm optimization algorithm are compared with results of previous work and it is observed that the results obtained by PSO algorithm are better than the previous result.[6]

OBJECTIVE

➢ **In this project, the main objective is to determine optimal solution of capacitated vehicle routing problem using PSO algorithm. By optimal solution, it means deriving the route of the system so that it gives the maximum profit.**

➢ **Though deriving the maximum profit is the main goal, total vehicle number and total time of the system configuration are also taken into consideration while evaluating the optimal solution.**

SYSTEM DESIGN

Constraints of Capacited VRP Algorithm

- **Vehicle capacity (C) constraint is observed**
- **Total tour time (M) constraints.**
- **Total demand (d_i) constraints.**

Every city must be served

Mathematical Model of VRP Algorithm

The Multi objective Profit Maximization Capacitated VRP model can be mathematically formulated as shown below:

$$i = 1$$

$$\text{Maximize Z} = \binom{n}{k} Pi^{(t)} \sum N \sum_{j=1}^{N} \quad \sum_{k=1}^{K} \quad C_{ij}x^{k}_{ij} \quad \dots \quad (1)$$
$$\sum_{i=1}^{N}$$

i.e. the maximization of total profit in the system, Subject to ;

$$P_i(t) = r_i(t) - e_i(t) \quad i = 1, 2, \dots, N \quad \dots \quad (2)$$

$$\sum_{i=1}^{N} \quad x^{k}_{ij} = y^{k}_{j}, \quad j = 1, 2, \dots, N \text{ for all k} \dots \quad (3)$$

$$\sum_{j=1}^{N} \quad x^{k}_{ij} = y^{k}_{i}, \quad i = 1, 2, \dots, N \text{ for all k} \dots \quad (4)$$

$$\sum_{k=1}^{K} \quad y^{k}_{i} = 1, \quad i = 1, 2, \dots, N \text{ for all k} \dots \quad (5)$$

[Every city is served.]

$$\sum_{i=1}^{N} \quad \sum_{j=1}^{N} \quad t^{j}_{i}x^{k}_{ij} + \sum_{i=1}^{N} \quad y^{k}_{i}T_{i} \leq M, \text{ for all k} \dots \quad (6)$$

[Total tour time is less than or equal to M.]

$$\sum_{i=1}^{N} \quad d_{i}y^{k}_{i} \leq C, \text{ for all k} \dots \quad (7)$$

[Total demand constraint.]

- C_{ij} = the cost of travelling from i^{th} city to j^{th} city.
- $r_i(t)$ = the return or earning for spending t time in the ith city.

- $e_i(t)$ = the expenses for spending t time in the ith city.
- $P_i(t)$ = the profit on the ith city = $r_i(t)$ - $e_i(t)$.
- S_i = the service time to supply the base demand in the ith city.
- t_i = the service time to supply the excess demand in i^{th} city.
- T_i = the total service time in the ith city = $(S_i + t_i)$.
- t_{ij} = the time for travelling from i^{th} city to j^{th} city.
- M = Total tour time
- x^k_{ij} = 1 if the vehicle k travels from city i to city j, else it is zero.
- N = the total number of cities in the system.
- K = the total number of vehicles/ salesmen in the system.
- y^k_j = 1 if the city j is visited by the vehicle k , else it is zero.
- u_i= base demand in i^{th} city.
- v_i = excess demand in city j .
- d_i = total demand in the city j= $(u_i + v_i t_i)$
- C = Capacity of each vehicle

Fitness function in our algorithm is as follows-
Fitness=(profit$^{\alpha}$)/(no_of_vehicle$^{\beta}$ * total_time$^{¥}$)
Where, α, β, ¥ are constants whose value depends on the priority that we want to assign for profit, number of vehicle and total time.

METHODOLOGY FOR IMPLEMENTATION

Flowchart of PSO Based Capacitated VRP Algorithm

Fig 2: PSO Flowchart

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION
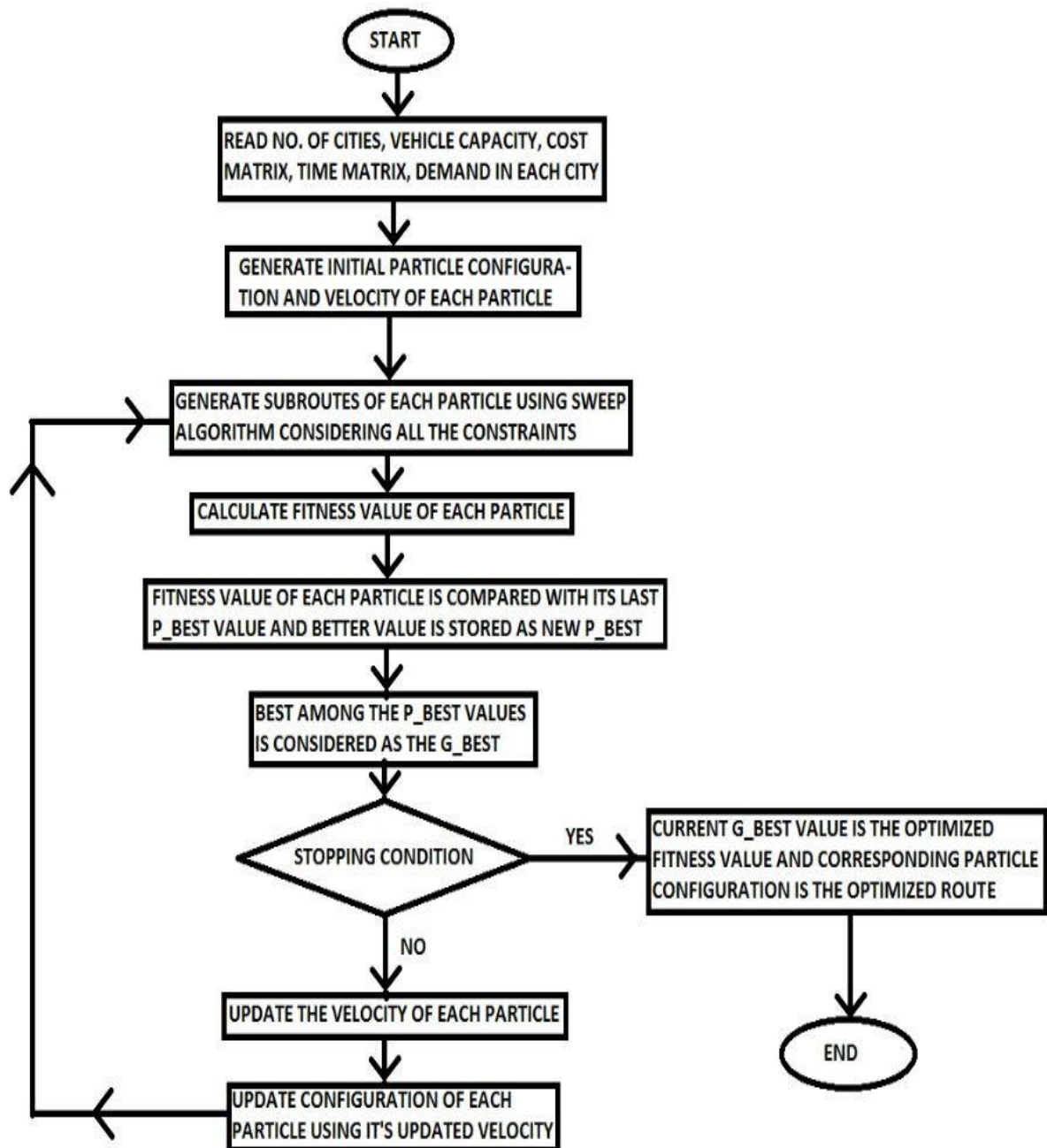
Flowchart of Sweep Algorithm

Fig 3: Sweep Flowchart

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION
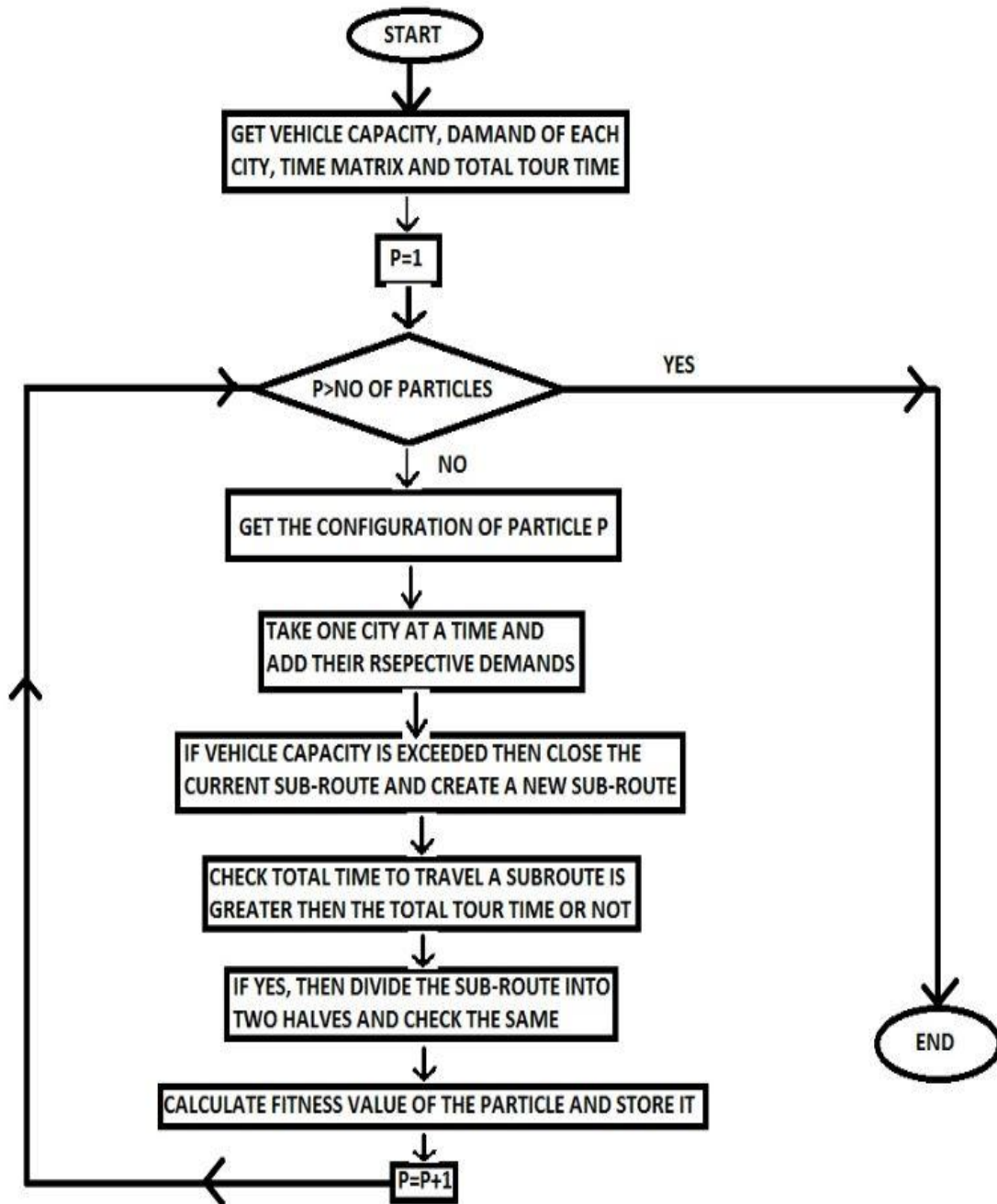
PSO Based Capacitated Profit Maximization VRP Algorithm (using Sweep Algorithm)

Step 1: **Read no. of cities,**
Read distance between cities,
Read demands in each city (base and excess demand),
Read vehicle capacity,
Read time matrix (time needed to travel between cities),
Read earnings and expenses in each city

Step 2: **Read number of particles (i)**

Step 3: **Generate initial solutions (x^0_i) using sweep technique as follows:**

Step 3.1. **We consider a route configuration and create sub-routes using this algorithm to find its fitness value.**

Step 3.2. **We add the demands of cities in the particles and check if it exceeds the vehicle capacity or not.**

Step 3.3. **If vehicle capacity exceeds, then close the current sub-route otherwise a new sub-route is created until all the cities are visited for the current particle.**

Step 3.4. **While creating the sub-routes, the total time to complete travelling the sub-route should not exceed the total tour time.**

Step 3.5. **If total tour time is exceeded then sub-routes are broken and called recursively and checked against the total tour time.**

Step 3.6. **After all the sub-routes are created for each particle, then its fitness value (total profit in our case) is calculated and stored.**

Step 4: **$pbest^0_i$ is memorized for each solution (fitness value) and $Gbest^0$ is the solution which provides best fitness value (in our case it is maximum profit). In each iteration, Pbest and Gbest values get updated by comparing the current value with the previous values.**

Step 5: **The velocity array (v^0_i) is obtained by choosing continuous numbers between 0 and the number of cities**

Step 6: **The following equation is used to update the velocity to get v^1_i**

$$\mathbf{v}^1_i = \omega^0 \mathbf{v}^0_i + \phi_1 \beta_1 \left(pbest^0_i - \mathbf{x}^0_i \right) + \phi_2 \beta_2 \left(gbest^0_i - \mathbf{x}^0_i \right)$$

Where, $w^0 = 0.6$, $\phi_1 = \phi_2 = 0.2$, $\beta_1 = 0.3$ and $\beta_2 = 0.5$

Step 7: **Now we update the solutions to get x^1_i. $x^1_i = x^0_i + v^1_i$**
Now,
If $x^1_i > x_{MAX}$ Then $x^1_i = x_{MAX}$
If $x^1_i < x_{MIN}$ Then $x^1_i = x_{MIN}$

Step 8: **Next, the solution arrays are decoded in order to obtain the route configurations and the total distance of each   particle. The numbers in the solutions are the rank of each city. The numbers are sorted increasingly. Thus, city 1 is the first and city 2 is the second. In case of ties between numbers, the velocity will be use as the rank numbers. Such that, the one with less velocity(v^1_i) will come first.**

Step 9: **Go to step 3 until all the number of iterations gets completed.**

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IMPLEMENTATION DETAILS

Illustration of Capacitated Multi Objective VRP using PSO algorithm

1. Get the cost matrix between the cities (no. Of cities 7).

From-to	Depot	1	2	3	4	5	6	7
Depot	0	18	21	11	15	21	25	12
1	18	0	21	24	32	37	36	16
2	21	21	0	15	24	40	45	30
3	11	24	15	0	10	26	33	23
4	15	32	24	10	0	20	30	26
5	21	37	40	26	20	0	13	23
6	25	36	45	33	30	13	0	20
7	12	16	30	23	26	23	20	0

2. Vehicle capacity is 15

3. Demand in each cities, di = [4 4 5 7 8 3 5] for i= 1, 2, ...7

4. Expense in each cities, ei = [5 40 28 26 15 17 20] for i= 1, 2, ...7

5. Earnings in each cities, ei = [135 180 148 126 118 147 100] for i= 1, 2, ...7

6. Profit in each cities, pi = [130 140 120 100 103 130 80] for i= 1, 2, ...7

7. Total profit = 803

8. We generate initial solution as,

$x^0_1 = $ [1 2 3 4 5 6 7],

$x^0_2 = $ [7 1 2 3 4 5 6],

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$x^0_3 = [6\ 7\ 1\ 2\ 3\ 4\ 5]$.

X^0_1 :
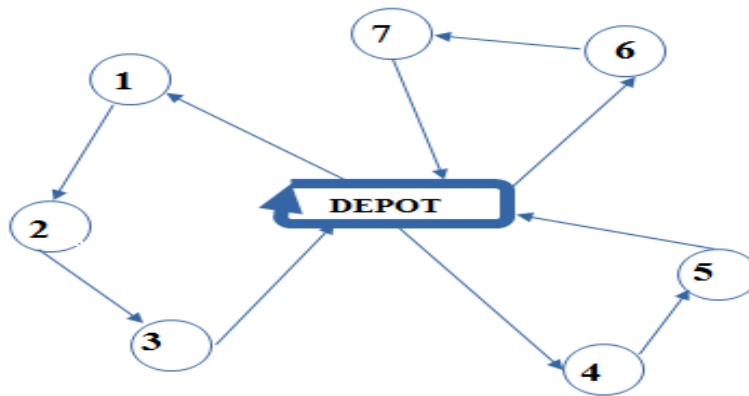
TOTAL COST :178
TOTAL PROFIT : 625

X^0_2:
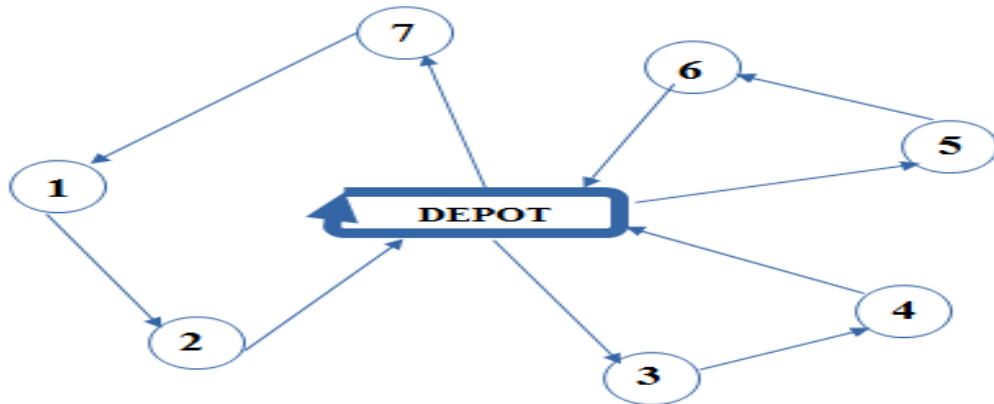
TOTAL COST :165
TOTAL PROFIT : 638

$X^0{}_3$:
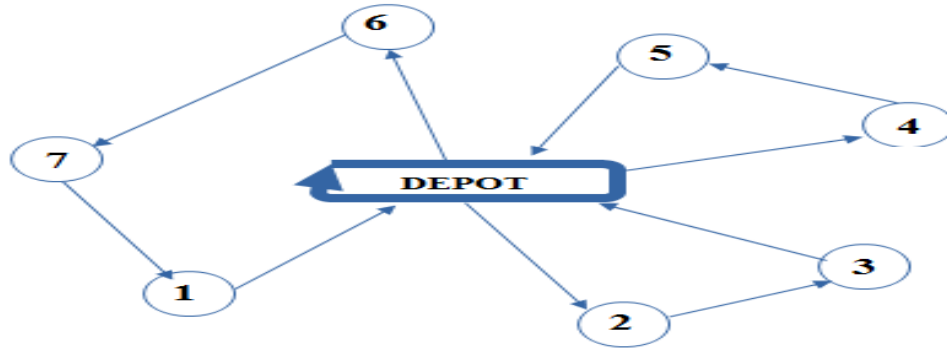
TOTAL COST :182
TOTAL PROFIT : 621

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9. Pbest$^0{}_i$ for each of x$^0{}_i$ is memorized as the fitness value of that solution and gbest^0 is obtained as the one with best fitness value. here that is x$^0{}_2$ which gives the fitness value 638

10. The velocity array (v$^0{}_i$) is obtained by choosing continuous.

numbers between 0 and the number of cities.

In this example, the velocity of each particle is randomly generated between [0; 7].

Suppose the velocity arrays are obtained;

V$^0{}_1$= [0.3 4.5 2.1 3.3 0.5 6.3 2.7],

V$^0{}_2$ = [1.2 0.7 6.4 3.5 1.2 3.3 5.5],

V$^0{}_3$ = [6.5 2.1 0.2 4.4 2.7 2.0 1.2].

11. The following equation is used to update the velocity to get

V$^1{}_i$ -

$$V^1{}_i = \omega^0 V^0{}_i + \Phi_1\beta_1(pbest^0{}_i - X^0{}_i) + \Phi_2\beta_2(gbest^0{}_i - X^0{}_i)$$

WHERE, $\omega^0 = 0.6$, $\Phi_1 = \Phi_2 = 0.2$, $\beta_1 = 0.3$ AND $\beta_2 = 0.5$

Particle 1:

$$V1_1 = 0.6 * \begin{bmatrix} 0.3 \\ 4.5 \\ 2.1 \\ 3.3 \\ 0.5 \\ 6.3 \\ 2.7 \end{bmatrix} + 0.2 * 0.3 * \begin{bmatrix} 1-1 \\ 2-2 \\ 3-3 \\ 4-4 \\ 5-5 \\ 6-6 \\ 7-7 \end{bmatrix} + 0.2*0.5 * \begin{bmatrix} 7-1 \\ 1-2 \\ 2-3 \\ 3-4 \\ 4-5 \\ 5-6 \\ 6-7 \end{bmatrix} = \begin{bmatrix} 0.78 \\ 2.6 \\ 1.16 \\ 1.88 \\ 0.20 \\ 3.68 \\ 1.52 \end{bmatrix}$$

$V1_1$ = [0.78 2.6 1.16 1.88 0.20 3.68 1.52]

Particle 2:

$$V1_2 = 0.6 * \begin{bmatrix} 1.2 \\ 0.7 \\ 6.4 \\ 3.5 \\ 1.2 \\ 3.3 \\ 5.5 \end{bmatrix} + 0.2 * 0.3 * \begin{bmatrix} 7-7 \\ 1-1 \\ 2-2 \\ 3-3 \\ 4-4 \\ 5-5 \\ 6-6 \end{bmatrix} + 0.2*0.5 * \begin{bmatrix} 7-7 \\ 1-1 \\ 2-2 \\ 3-3 \\ 4-4 \\ 5-5 \\ 6-6 \end{bmatrix} = \begin{bmatrix} 0.72 \\ 0.42 \\ 3.84 \\ 2.10 \\ 0.72 \\ 1.98 \\ 3.30 \end{bmatrix}$$

$V1_2$ = [0.72 0.42 3.84 2.10 0.72 1.98 3.30]

Particle 3 :

$$V1_3 = 0.6 * \begin{bmatrix} 6.5 \\ 2.1 \\ 0.2 \\ 4.4 \\ 2.7 \\ 2.0 \\ 1.2 \end{bmatrix} + 0.2 * 0.3 * \begin{bmatrix} 6-6 \\ 7-7 \\ 1-1 \\ 2-2 \\ 3-3 \\ 4-4 \\ 5-5 \end{bmatrix} + 0.2*0.5 * \begin{bmatrix} 7-6 \\ 1-7 \\ 2-1 \\ 3-2 \\ 4-3 \\ 5-4 \\ 6-5 \end{bmatrix} = \begin{bmatrix} 4.00 \\ 0.66 \\ 0.22 \\ 2.74 \\ 1.72 \\ 1.30 \\ 0.82 \end{bmatrix}$$

$V1_3$ = [4.00 0.66 0.22 2.74 1.72 1.30 0.82]

- -

12. Now we update the solutions to get X^1_1.

$X^1_i = x^0_i + v^1_i$

NOW,

IF $X^1_i > xMAX$ THEN $X^1_i = xMAX$

IF $X^1_i < xMIN$ THEN $X^1_i = xMIN$

<u>PARTICLE 1(X^1_1)</u>

$$MIN \quad \left(7.00, \begin{pmatrix} 1 + 0.78 \\ 2 + 2.6 \\ 3 + 1.16 \\ 4 + 1.88 \\ 5 + 0.20 \\ 6 + 3.68 \\ 7 + 1.52 \end{pmatrix}\right) = \begin{pmatrix} 1.78 \\ 4.60 \\ 4.16 \\ 5.88 \\ 5.20 \\ 7.00 \\ 7.00 \end{pmatrix} = X^1_1$$

$X^1_1 = [1.78\ 4.60\ 4.16\ 5.88\ 5.20\ 7.00\ 7.00]$

<u>PARTICLE 1(X^1_2)</u> :

$$MIN \quad \left(7.00, \begin{pmatrix} 7 + 0.72 \\ 1 + 0.42 \\ 2 + 3.84 \\ 3 + 2.10 \\ 4 + 0.72 \\ 5 + 1.98 \\ 6 + 3.30 \end{pmatrix}\right) = \begin{pmatrix} 7.00 \\ 1.42 \\ 5.84 \\ 5.10 \\ 4.72 \\ 6.98 \\ 7.00 \end{pmatrix} = X^1_2$$

$X^1_2 = [7.00\ 1.42\ 5.84\ 5.10\ 4.72\ 6.98\ 7.00]$

<u>PARTICLE 1(X^1_3)</u> :

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$$\text{MIN} \quad \left(7.00, \begin{pmatrix} 6 + 4.00 \\ 7 + 0.66 \\ 1 + 0.22 \\ 2 + 2.74 \\ 3 + 1.72 \\ 4 + 1.30 \\ 5 + 0.82 \end{pmatrix}\right) = \begin{pmatrix} 7.00 \\ 7.00 \\ 1.22 \\ 4.74 \\ 4.72 \\ 5.30 \\ 5.82 \end{pmatrix} = X^1{}_3|$$

$X^1{}_3 = [7.00\ 7.00\ 1.22\ 4.74\ 4.72\ 5.30\ 5.82]$

13 . Next, the solution arrays are decoded in order to Obtain the route configurations and the total

Distance of each particle. In this example, the position Array of particle 1 is

$x^1{}_1 = [1.78\ 4.60\ 4.16\ 5.88\ 5.20\ 7.00\ 7.00]$

The numbers in the elements are the rank of each customer. The numbers are sorted increasingly. Thus,

City 1 is the first and city 3 is the second. In case of ties numbers, city 6 and 7 for this particle, the

Velocity will be use as the rank numbers. For example, $V^1{}_6 = 3.58$ and $V^1{}_7 = 1.42$ (the velocity Element 6 = 3.58 and element 7 = 1.42). In this case, Customer 7 is served before customer 6. The route Configuration of particle 1 is 1-3-2-5-4-7-6 which the Vehicle capacity limit divides it into 3 trips. The fitness Value is 638.

Particle 2 is $x^1{}_2 = [7.00\ 1.42\ 5.84\ 5.10\ 4.72\ 6.98\ 7.00]$ which can be routed as 6-1-4-3-2-5-7. Likewise, the vehicle capacity limit divides it into 3 trips. The fitness value is 211. Particle 3 is $x^1{}_3 = [7.00\ 7.00\ 1.22\ 4.74\ 4.72\ 5.30\ 5.82]$ which Can be routed as 7-6-1-3-2-4-5. The vehicle capacity limit Divides it into 3 trips. The fitness value is 621.

14 . The next iteration starts after the pbest and gbest are Updated.

Pbest1i = pbest0i if fitness value of x1i is not better than $X_0{}^i$

And if, fitness value of $X_1{}^i$ is better than x0i then pbest1i is Updated as the fitness value of x1i.

Gbest1 is obtained as the best among the values of pbest1i.

Iteration(t)	$F(X_1^1)$	$F(pbest_1^1)$	$F(X_2^1)$	$F(pbest_2^1)$	$F(X_3^1)$	$F(pbest_3^1)$	$F(gbest_i)$
0	625	625	638	638	621	621	638
1	621	625	592	638	614	621	638
2	593	625	592	638	614	621	638
3	593	625	592	638	593	621	638

Table 1: Pbest and Gbest values for particles

RESULTS / SAMPLE OUTPUT

SAMPLE OUTPUT FOR CITY 80, PARTICLES 20, ITERATIONS 200 AND FITNESS FUNCTION

F=(PROFIT$^{\alpha}$)/(VEHICLE$^{\beta}$ * TIME$^{¥}$) WHERE α=0.8, β=0.2, ¥=0.4

INPUT:

Vehicle Capacity: 30

Total Tour Time: 200

Cost Matrix

0 36 98 99 53 89 37 58 46 32 95 20 52 32 10 62 43 42 42 33 96 79 23 92 76 89 25 53 69 48 26 51 97 34 10 25 47 89 92 10 52 77 82 60 47 50 23 30 37 77 13 77 88 15 16 36 65 23 80 45 46 56 88 23 32 93 66 53 56 18 93 74 78 59 61 86 48 63 85 85 92

92 0 77 53 75 35 34 26 58 59 18 60 54 16 15 99 23 80 49 16 10 31 52 21 19 43 84 86 21 91 81 71 51 22 97 31 22 91 89 57 97 73 76 24 97 50 10 67 29 22 88 52 59 10 29 75 11 65 76 56 93 89 29 81 84 85 76 98 85 47 53 54 51 28 77 55 44 13 81 95 76

69 61 0 21 84 47 24 45 44 51 12 58 39 59 10 23 35 21 97 90 82 17 63 44 97 76 90 36 28 87 61 16 80 94 77 25 88 13 73 82 11 26 47 70 85 19 71 22 60 51 75 15 74 93 27 91 50 87 34 34 83 30 83 20 46 58 12 44 61 50 49 19 40 84 95 63 31 42 62 33 38

48 55 90 0 55 30 44 64 70 83 54 83 55 55 73 39 63 65 15 92 79 16 40 77 36 37 11 97 99 58 32 94 74 67 90 53 75 23 94 10 65 91 47 18 61 80 49 61 77 12 74 96 26 61 91 72 26 61 38 80 44 33 38 42 75 77 73 81 39 44 70 52 53 94 92 61 59 16 39 48 66

56 58 34 37 0 86 17 69 76 69 41 20 55 30 32 96 81 86 39 43 87 81 22 55 93 13 90 70 88 17 66 57 38 13 98 94 71 19 52 73 11 24 62 49 20 55 78 51 96 12 71 71 53 74 24 47 80 16 50 46 70 73 17 50 93 62 91 36 40 22 15 95 65 59 99 30 97 54 22 26 82

72 99 49 78 65 0 58 39 47 30 19 55 63 28 87 98 95 92 19 76 10 70 37 38 29 60 29 69 93 93 10 32 87 96 18 26 83 17 14 70 73 52 39 94 20 54 17 26 43 17 46 13 76 49 80 90 23 40 31 22 14 79 17 75 39 70 58 44 59 22 19 77 20 98 51 58 98 34 15 31 38

48 37 47 63 63 70 0 84 46 80 16 49 10 71 68 88 47 40 48 85 43 36 71 89 68 65 81 52 27 22 83 40 69 36 15 20 11 87 67 81 19 92 59 78 50 18 43 70 85 79 26 39 76 56 32 62 37 70 81 67 39 63 47 49 42 70 32 84 72 13 55 62 22 99 65 33 39 72 36 70 88

18 93 86 51 33 82 33 0 18 71 64 77 23 19 52 99 93 86 40 51 56 69 72 70 62 16 73 65 63 64 33 31 27 26 17 52 37 98 26 86 28 99 46 39 55 86 41 58 30 20 80 87 32 84 54 97 87 81 45 12 34 53 59 95 56 27 32 78 95 17 56 35 42 65 17 43 26 77 46 86 68

56 35 39 33 76 58 32 57 0 23 17 46 35 31 24 77 55 92 91 18 20 91 16 60 10 21 84 17 30 34 68 39 20 77 70 11 87 43 47 64 23 61 78 91 48 64 28 62 79 38 95 58 52 83 40 71 62 16 60 83 33 89 79 83 33 23 73 19 34 99 63 10 98 61 18 19 54 52 80 87 17

69 15 94 74 53 10 11 88 27 0 68 82 76 58 81 81 93 24 35 22 75 61 15 31 49 84 32 53 22 95 82 17 74 46 54 32 58 83 67 70 40 10 81 42 39 56 60 71 80 75 88 47 14 49 73 84 30 25 26 39 83 66 75 65 88 92 47 41 82 67 79 81 20 88 72 94 79 29 15 55 76

84 47 98 39 33 40 52 89 70 59 0 61 22 80 39 23 43 83 71 93 43 39 19 97 21 54 96 51 19 57 90 49 51 87 70 50 75 54 24 77 15 78 85 55 74 89 64 56 96 94 10 44 11 92 74 78 41 72 82 22 45 95 14 72 77 26 68 47 89 22 92 70 91 18 39 25 64 74 20 31 42

96 82 92 23 30 90 39 95 91 77 60 0 13 59 75 40 91 40 90 37 81 45 34 44 60 59 38 93 15 32 47 31 49 58 66 93 34 28 68 76 10 40 69 11 71 14 61 46 91 90 33 57 93 94 72 73 48 69 17 14 62 76 17 43 83 16 83 33 57 30 93 95 12 86 21 64 92 94 69 85 70

33 86 99 74 47 58 14 61 39 39 12 95 0 70 92 63 18 64 20 29 25 90 67 30 78 87 69 19 45 57 53 66 99 67 84 98 68 88 44 62 84 40 77 53 11 48 26 30 54 98 53 23 35 65 46 77 52 68 56 10 20 15 86 92 40 79 10 79 86 54 56 42 70 26 30 93 11 80 42 39 53

89 65 51 11 15 34 91 12 68 88 30 95 22 0 12 19 66 24 69 21 83 75 92 49 95 64 53 42 10 55 22 89 60 37 17 21 83 54 13 78 38 21 12 73 58 13 71 22 15 40 68 11 18 25 22 54 67 66 47 69 46 51 35 91 84 58 66 75 13 64 60 87 22 16 31 64 60 74 41 23 19

85 92 95 94 32 10 76 23 51 83 92 13 88 49 0 23 53 93 24 62 95 97 68 85 44 94 28 50 28 84 43 12 30 76 12 82 34 57 98 63 46 27 80 77 53 65 62 46 67 93 81 46 37 90 35 55 61 54 70 95 24 61 51 73 76 37 92 82 58 63 34 74 78 38 12 92 92 80 61 13 16

53 34 61 27 32 12 54 50 56 70 47 35 71 28 43 0 95 16 33 23 78 33 15 98 84 40 36 61 63 95 88 87 78 18 94 49 46 37 60 62 40 88 27 65 99 11 33 42 26 67 93 67 38 67 91 38 21 94 68 87 68 41 96 83 23 86 70 78 62 11 13 48 39 97 26 13 18 49 62 52 58

52 27 18 82 41 25 93 79 17 43 26 34 60 78 38 22 0 57 85 13 55 58 18 91 93 78 82 27 33 15 30 70 16 59 33 43 64 77 97 37 67 76 69 56 95 20 20 36 77 26 14 12 60 78 57 98 72 50 18 43 16 53 56 63 94 99 14 80 50 16 90 99 51 71 47 75 79 54 88 52 71

96 32 67 41 84 69 56 19 94 45 73 58 79 56 61 96 93 0 75 53 95 73 44 42 39 21 56 85 77 64 18 17 21 22 23 16 16 14 22 41 89 26 64 15 45 92 88 65 37 47 33 67 23 63 93 49 21 62 11 59 59 26 44 46 69 25 59 39 35 40 35 56 91 75 86 16 13 87 34 80 81

34 99 21 22 18 23 15 33 47 49 35 28 74 52 98 62 77 21 0 95 16 65 66 52 50 74 53 72 69 60 58 81 57 48 72 85 68 32 11 16 17 21 19 87 59 17 12 19 21 73 15 52 59 81 11 62 42 35 24 93 20 59 51 33 90 90 97 72 64 11 82 19 64 86 20 59 32 76 67 30 94

94 58 98 17 19 98 45 19 57 73 41 94 38 54 35 90 75 53 20 0 29 95 72 33 80 54 37 23 37 52 94 44 47 22 18 17 56 81 25 27 29 77 27 54 23 27 67 44 38 27 47 35 41 13 45 75 52 17 13 47 76 71 41 30 59 49 18 53 52 99 22 47 43 83 58 55 76 71 45 86 40

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

95 72 25 45 36 98 42 69 55 11 84 20 96 15 87 13 48 24 34 25 0 54 79 50 24 28 57 30 13 93 65 96 41 90 37 27 91 51 98 29 53 42 72 10 19 92 33 64 47 79 15 73 38 19 23 67 65 95 11 27 14 18 27 87 83 87 75 41 55 44 97 82 45 54 64 33 68 77 87 31 75

38 48 46 64 97 26 73 90 54 33 62 26 86 62 33 77 37 61 21 46 23 0 24 24 46 27 51 87 20 29 52 17 34 61 76 84 13 43 71 57 43 26 82 25 60 87 28 50 62 90 97 37 39 26 12 80 28 27 66 70 20 16 52 67 29 32 64 68 44 80 66 29 18 44 81 82 40 45 17 81 78

88 46 35 72 24 11 34 73 48 53 47 23 16 33 21 80 93 61 95 23 87 73 0 22 23 28 79 90 42 39 21 98 80 78 64 56 99 14 80 58 90 91 29 48 82 82 69 86 72 18 16 57 16 14 95 87 80 81 43 53 33 50 25 82 54 19 78 16 43 31 37 83 58 85 11 19 85 71 22 60 94

71 56 86 60 61 58 89 76 20 46 27 94 25 55 90 92 82 40 74 78 65 97 51 0 93 62 21 22 18 25 20 32 84 21 96 50 17 19 91 89 21 29 51 62 73 84 42 46 73 72 73 85 56 34 70 53 69 97 88 49 58 59 99 98 20 26 46 49 66 45 49 85 48 25 53 80 92 45 72 97 80

97 48 92 90 94 45 14 93 80 34 80 88 78 75 60 89 96 62 47 68 61 92 46 10 0 23 74 70 95 38 55 98 72 18 30 22 45 99 30 49 26 14 44 62 24 51 88 37 38 22 37 46 63 14 52 73 27 24 71 40 27 97 70 64 85 70 46 37 91 14 99 90 53 24 39 67 38 34 86 63 19

69 35 19 81 69 73 61 62 63 60 28 41 21 53 68 43 99 43 98 68 24 96 82 38 23 0 14 71 10 77 43 67 57 89 79 26 42 37 83 19 91 88 78 14 41 99 99 85 87 19 12 23 48 23 65 37 23 61 46 87 51 80 51 29 37 41 68 27 89 14 60 62 12 57 87 18 11 43 58 72 56

77 98 14 10 59 32 83 57 89 96 72 38 96 36 21 43 68 64 62 40 38 86 66 83 51 70 0 20 89 51 96 69 45 49 80 66 31 98 39 68 55 98 73 36 15 19 46 54 25 57 18 35 24 39 49 42 28 83 21 55 42 25 71 39 90 51 31 12 35 36 80 21 82 66 53 30 90 51 16 32 80

74 74 53 42 28 29 15 35 14 34 59 93 89 22 89 65 19 26 32 57 78 85 36 70 50 87 98 0 46 61 86 82 19 16 23 38 35 39 81 32 21 45 54 28 78 82 79 73 45 59 83 93 37 48 63 89 97 93 27 52 87 65 55 76 52 52 22 36 14 16 52 34 65 22 72 73 35 52 75 70 19

31 57 23 91 70 46 45 38 86 10 25 45 85 94 55 14 98 56 59 24 84 56 13 68 15 43 13 99 0 39 95 22 41 99 84 55 48 95 31 11 13 45 66 83 84 12 31 50 54 53 74 95 51 31 88 72 42 89 98 34 33 38 11 71 85 49 63 49 60 71 16 55 85 52 76 87 64 74 31 87 58

80 55 33 59 63 67 20 85 40 42 57 13 49 44 24 64 71 54 36 52 57 40 84 21 10 74 58 81 67 0 91 63 72 59 66 79 53 46 47 69 79 54 60 58 35 64 13 42 47 59 92 19 32 51 93 23 13 99 63 72 13 16 91 91 83 79 52 73 26 97 37 28 55 51 38 20 93 70 62 17 36

61 88 54 98 53 72 30 46 61 89 85 89 77 25 48 24 21 62 17 98 13 71 41 44 98 38 89 36 76 31 0 11 38 94 85 85 97 99 12 93 74 20 23 74 20 54 15 71 93 95 76 59 65 53 71 83 37 10 33 68 29 45 54 32 28 16 56 93 18 11 35 70 94 73 52 27 87 33 13 95 27

42 31 52 61 93 73 52 95 58 53 96 78 87 81 11 56 19 28 97 71 88 39 59 70 19 15 64 89 59 53 13 0 74 95 63 16 31 61 35 17 28 98 83 45 17 79 35 43 16 60 98 87 50 17 56 26 83 15 27 67 25 81 87 61 66 59 67 46 62 93 15 71 48 99 21 31 73 29 43 62 19

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

56 27 26 58 38 44 42 60 67 37 80 99 58 30 20 29 38 75 81 70 88 73 70 13 22 32 46 23 60 33 32 12 0 55 24 81 25 87 53 34 29 26 44 91 65 30 85 83 51 95 70 14 27 65 33 37 10 79 96 40 71 70 26 87 75 24 32 48 39 84 19 84 75 25 33 53 38 66 84 74 90

57 87 56 32 99 57 83 80 97 66 62 37 15 49 56 99 34 30 86 89 79 60 24 74 52 95 82 15 87 60 34 39 82 0 17 55 69 36 13 61 92 91 41 88 21 72 46 68 27 90 15 95 72 23 78 67 32 36 80 94 34 39 69 88 83 13 14 66 70 70 69 72 34 27 34 36 22 47 22 17 69

45 82 44 12 50 92 43 78 34 67 93 85 28 66 63 53 69 88 61 58 85 42 88 84 36 43 84 71 30 11 41 39 55 95 0 98 51 77 73 35 93 84 30 87 95 22 97 32 47 98 46 82 10 77 78 16 80 51 76 23 58 55 67 17 82 20 19 76 50 86 29 56 20 93 48 53 54 83 73 36 33

15 83 34 86 19 58 68 24 88 97 41 39 21 93 37 93 29 56 62 47 89 99 64 33 86 65 33 92 34 86 12 58 89 86 81 0 38 24 22 88 56 36 66 40 29 58 35 80 32 25 63 43 84 24 39 84 28 54 80 37 72 54 42 12 81 96 96 74 45 18 21 24 13 58 72 86 10 60 26 87 74

89 54 47 23 99 67 47 91 37 54 77 47 69 31 77 66 77 37 51 74 57 19 92 49 77 96 97 60 56 20 98 25 66 40 48 58 0 76 24 74 36 47 14 65 25 84 19 72 65 57 49 88 81 21 39 57 21 57 79 82 19 38 63 48 46 34 58 48 45 93 94 12 29 96 12 12 58 56 86 94 53

24 25 83 50 22 84 77 68 71 60 74 19 73 59 38 80 90 31 49 22 57 66 22 31 29 34 16 65 16 48 22 15 91 85 37 94 85 0 98 43 80 10 42 49 26 41 12 71 23 52 78 98 25 43 18 45 10 90 33 78 18 58 61 28 25 13 98 30 45 84 45 90 10 98 99 84 38 27 71 82 51

65 38 75 38 61 70 59 79 91 14 13 64 42 45 55 76 85 44 65 39 35 63 35 74 24 84 26 95 78 42 42 11 24 22 80 87 75 38 0 71 83 67 32 90 79 36 52 62 17 93 84 90 17 43 84 64 18 80 18 69 13 89 10 80 66 71 37 89 74 90 38 66 64 69 50 38 57 23 71 74 16

62 96 59 92 44 36 50 64 33 84 74 18 86 77 34 20 70 36 48 34 25 76 75 36 60 18 23 25 89 52 28 17 91 37 61 36 70 59 87 0 56 76 90 77 34 83 11 77 88 37 27 84 85 70 24 38 86 29 90 84 64 52 58 92 69 32 46 94 55 64 64 85 86 98 65 33 46 41 63 46 84

18 66 51 97 56 85 34 63 32 77 91 46 75 91 51 37 86 70 74 87 72 62 46 63 96 17 65 78 76 27 45 41 49 92 11 99 34 99 35 67 0 39 94 96 35 52 42 99 67 59 79 67 33 54 17 35 82 94 43 36 30 34 94 45 16 96 73 98 88 85 25 75 57 89 32 52 58 53 87 54 40

78 41 83 46 83 48 38 72 49 46 60 25 18 63 20 57 77 97 58 74 65 21 94 76 79 47 69 35 73 87 58 92 64 87 66 18 11 96 91 29 99 0 27 14 70 82 52 12 28 10 63 57 15 86 48 97 58 46 56 48 92 40 81 19 58 66 96 24 55 30 93 51 17 29 61 84 13 76 20 80 22

59 19 84 69 38 14 56 10 11 42 26 52 78 95 22 19 43 34 64 44 27 84 83 24 66 56 90 28 98 50 35 40 90 54 17 67 18 94 22 28 32 66 0 46 48 26 87 73 95 25 69 76 28 90 41 79 21 86 10 44 27 64 36 49 55 91 35 30 72 26 11 13 32 84 88 29 34 40 41 25 25

15 50 88 25 59 14 29 61 74 18 50 63 99 60 98 95 74 49 73 44 28 17 41 10 54 12 99 64 34 65 99 53 48 80 99 67 15 45 54 37 47 34 35 0 69 22 16 22 38 68 99 62 75 83 57 19 18 74 17 89 83 72 75 79 41 20 50 92 24 70 40 32 40 74 60 77 71 51 38 32 37

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

16 78 32 42 55 94 25 82 23 52 55 23 91 59 58 98 67 34 55 99 66 43 63 64 87 17 72 11 24 39 97 75 24 57 77 91 66 62 72 75 86 72 15 66 0 12 27 49 89 38 69 31 65 77 94 46 49 91 13 50 44 57 76 65 44 11 51 35 86 23 37 36 59 13 16 69 97 68 21 43 82

79 65 66 68 20 19 75 89 61 69 47 33 40 91 18 68 77 85 30 47 42 55 14 15 47 13 29 63 59 62 79 60 28 24 87 88 87 46 71 31 73 48 68 82 82 0 15 90 25 97 74 82 28 31 92 31 52 39 86 88 20 72 10 22 92 97 39 42 92 78 31 62 50 98 61 75 11 60 29 38 89

80 55 45 79 43 93 61 18 39 35 94 48 24 52 83 78 54 32 74 36 72 98 65 13 63 56 70 50 21 55 23 44 93 25 32 70 38 21 31 70 92 64 25 10 19 14 0 80 37 97 59 30 62 51 87 71 42 40 51 85 86 35 96 73 59 58 79 79 44 84 92 56 91 89 48 91 52 23 45 28 49

44 89 32 78 51 94 80 37 66 27 92 72 68 92 84 84 96 21 12 20 37 83 17 47 92 41 96 17 34 67 90 69 96 71 22 78 11 95 55 86 30 83 95 88 72 41 81 0 52 30 30 54 61 26 95 23 76 80 46 27 84 44 20 48 76 86 28 71 92 73 55 25 99 39 50 61 82 10 14 50 34

90 44 76 70 75 14 85 49 88 99 60 31 84 75 43 93 69 99 28 66 39 36 19 30 97 19 24 95 65 29 68 82 79 81 12 36 28 69 29 47 80 91 83 98 51 66 69 69 0 66 11 97 16 14 55 24 16 94 14 74 15 74 31 42 35 12 56 35 79 28 68 94 40 63 98 28 11 65 92 17 49

73 71 63 70 36 65 69 51 64 71 99 64 55 44 86 32 58 87 91 78 77 49 11 23 44 27 81 59 47 87 59 74 44 97 72 26 95 50 55 42 18 61 31 25 82 46 43 77 47 0 66 72 41 69 68 23 78 90 45 47 60 32 97 89 37 87 30 77 24 81 82 54 44 42 91 69 73 45 87 90 18

33 28 37 62 93 14 83 79 71 97 38 28 77 60 82 52 75 14 62 61 19 75 23 95 66 64 79 16 46 69 96 74 53 92 16 64 49 71 73 94 13 18 99 73 56 95 56 15 86 54 0 78 57 13 78 87 90 95 82 41 78 74 67 96 24 35 63 94 77 21 66 26 67 52 59 67 89 15 38 88 19

54 10 82 86 61 58 32 39 36 60 11 20 80 85 39 90 55 80 22 78 54 47 51 72 99 65 53 48 46 78 48 36 22 15 24 83 34 17 49 94 26 36 15 35 98 54 52 60 61 62 93 0 97 72 12 39 66 30 67 64 73 78 47 88 65 47 31 30 75 14 45 36 71 99 81 46 25 84 36 23 91

34 54 62 74 37 46 91 78 41 98 98 46 55 53 68 73 11 47 81 44 44 35 37 14 22 61 60 78 10 93 23 42 67 76 71 44 38 49 96 13 93 93 44 53 29 17 15 80 97 93 75 36 0 36 92 11 93 62 13 41 85 58 68 99 32 39 86 15 24 61 18 70 27 11 41 84 28 71 13 59 19

86 86 96 91 40 64 75 95 65 42 75 32 13 21 23 91 16 81 60 50 20 75 66 94 36 88 15 48 45 48 77 94 43 93 96 82 68 64 77 45 12 31 66 19 63 99 62 57 47 75 86 38 72 0 50 91 39 41 17 81 74 19 62 92 41 23 43 77 30 94 25 68 22 22 57 11 31 98 70 90 23

21 82 79 93 31 27 26 14 58 56 67 72 66 46 35 29 20 37 23 43 31 89 29 34 18 17 22 18 37 27 79 60 12 38 57 75 71 57 26 62 18 92 79 53 20 62 90 33 50 10 82 29 88 67 0 85 77 78 32 96 77 70 24 80 68 65 74 51 43 54 72 43 42 58 29 74 49 13 78 38 90

98 11 51 81 77 33 69 17 92 79 16 15 67 83 48 39 87 26 13 19 99 27 60 18 76 10 43 26 98 32 56 40 19 82 68 90 79 87 14 77 49 13 65 65 43 52 71 33 81 50 77 69 94 35 26 0 99 66 36 95 23 59 58 93 65 18 43 95 40 75 20 18 94 45 16 16 88 94 85 83 44

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

95 67 22 66 61 76 86 79 61 50 24 33 22 44 90 23 70 61 63 77 84 86 76 33 46 77 47 33 38 16 98 58 87 56 21 53 93
82 85 21 87 73 79 58 45 58 10 56 75 50 93 13 22 56 14 95 0 96 26 31 80 38 93 63 66 81 96 78 22 70 75 11 33 82 88
66 44 97 44 48 88

80 58 71 21 93 70 20 26 38 24 60 25 98 62 31 29 80 36 10 91 22 75 87 76 76 52 57 70 59 74 92 72 76 34 76 50 15
84 64 76 17 79 50 19 18 41 82 12 70 91 17 53 37 36 68 47 27 0 64 60 52 56 27 41 60 71 86 30 56 95 74 72 15 60 40
20 42 89 83 76 97

85 10 41 58 56 60 43 42 47 39 40 96 96 36 84 21 18 19 11 71 59 52 40 18 59 23 45 36 45 25 39 16 92 52 42 75 98
79 55 32 24 94 15 57 54 93 41 76 60 18 28 36 85 52 63 90 63 62 0 59 69 28 49 46 93 38 36 87 70 45 95 36 83 32 36
58 30 11 99 23 97

77 90 39 36 38 19 68 48 15 54 33 83 43 24 82 95 38 24 92 63 19 44 15 83 55 74 90 39 75 16 34 96 76 12 37 58 74
37 87 76 68 41 69 62 62 66 83 13 86 30 15 39 62 86 30 23 75 65 80 0 32 88 31 14 74 86 97 57 89 47 57 54 56 92 29
44 91 19 17 97 28

25 65 92 84 34 88 47 84 36 79 79 79 76 46 17 58 29 46 28 64 58 35 44 22 95 49 14 30 56 88 33 80 24 59 55 95 82
64 76 65 58 15 47 65 53 14 65 25 44 58 49 35 49 67 77 28 49 54 96 99 0 88 15 37 91 19 69 27 79 26 49 57 48 78 90
47 85 66 93 31 13

86 68 60 63 88 48 28 64 56 43 83 74 49 51 58 91 33 74 82 12 40 67 91 11 77 81 95 81 64 27 37 54 53 55 64 60 22
44 22 31 57 27 39 94 21 92 55 48 29 74 57 70 61 37 70 20 17 36 51 73 55 0 78 28 61 32 88 19 88 53 84 71 75 99 42
16 60 35 76 28 80

26 70 79 17 25 79 83 41 91 12 47 44 82 54 13 15 16 30 87 71 89 63 44 29 96 41 35 20 31 13 22 26 56 12 69 88 32
39 99 60 39 93 64 43 28 29 27 92 39 42 28 80 81 89 23 24 55 42 84 97 57 71 0 36 66 25 97 20 58 95 11 84 56 22 42
80 58 64 11 91 76

14 30 81 50 29 50 10 28 66 12 11 29 78 74 33 13 30 68 42 71 72 83 43 55 47 72 73 83 92 62 27 25 78 53 34 33 37
98 54 14 56 55 30 44 72 18 78 24 59 16 72 15 53 61 62 92 85 38 17 16 86 80 18 0 43 83 15 23 81 59 65 56 32 98 28
91 49 57 94 14 59

24 54 62 70 51 93 85 52 12 95 88 12 22 77 43 40 38 99 22 39 69 37 64 14 75 61 62 16 88 10 14 11 81 21 36 43 28
83 99 21 57 12 11 52 47 47 29 89 56 41 77 58 37 68 99 18 52 47 11 52 77 55 60 94 0 43 94 89 47 26 47 63 59 21 52
77 98 51 61 19 49

22 36 17 76 81 72 64 22 21 60 35 54 84 31 51 64 45 81 32 24 45 83 79 87 56 45 68 90 28 71 53 24 53 67 61 99 10
39 56 46 56 55 42 42 52 88 60 63 28 87 61 90 12 43 84 96 39 40 75 79 97 48 32 88 77 0 33 27 42 93 60 26 43 60 89
22 70 85 39 73 35

78 44 81 32 62 83 87 66 23 55 33 96 18 59 54 95 46 95 46 63 27 36 19 48 26 99 73 18 41 60 81 64 32 79 72 39 70
81 27 66 59 51 70 93 73 60 77 89 71 40 15 78 15 87 45 10 65 64 39 47 67 14 72 24 21 50 0 49 21 92 86 39 65 59 28
31 84 31 26 79 56

65 61 44 20 90 86 47 85 42 31 31 89 79 56 20 37 71 14 44 88 15 66 90 23 95 31 11 73 18 10 52 67 23 61 92 88 73
83 82 73 83 23 95 50 41 12 78 15 35 37 24 52 40 66 94 85 96 50 26 69 20 52 15 76 26 25 66 0 88 31 75 41 59 13 33
29 62 99 60 81 29

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

52 28 16 50 95 77 36 23 47 78 86 21 22 88 30 66 36 18 38 94 61 32 17 31 91 90 77 83 55 88 53 27 13 43 50 93 66 17 73 93 11 25 95 95 40 44 72 92 11 95 78 35 39 13 56 92 99 90 78 53 74 38 10 10 54 95 48 47 0 16 99 52 55 57 26 79 75 16 70 54 56

96 89 30 59 17 50 59 23 79 15 68 85 59 78 70 91 75 71 57 94 99 28 70 77 91 42 91 83 28 28 98 43 67 83 44 53 34 13 37 52 92 36 10 27 80 30 26 76 18 40 78 15 57 68 69 29 42 40 31 48 27 30 99 72 56 31 29 37 56 0 58 73 40 32 75 89 99 39 76 73 73

51 39 39 55 62 99 50 32 99 49 95 39 98 46 84 23 73 20 79 21 74 15 68 63 21 87 70 28 38 66 69 31 97 69 71 24 74 19 43 22 58 22 27 44 52 12 98 92 69 33 66 10 50 34 98 45 35 97 74 16 21 11 56 47 79 89 35 52 90 16 0 94 70 60 90 68 38 83 69 36 68

39 39 70 38 60 11 78 95 10 47 33 69 37 90 25 43 13 94 55 19 88 30 69 89 12 16 66 81 84 76 97 80 54 62 55 88 14 92 28 28 42 30 18 31 10 43 40 22 58 33 60 86 76 65 82 87 78 97 84 37 32 35 48 24 68 17 42 73 94 51 56 0 89 35 48 27 58 22 59 99 82

18 78 42 24 17 14 92 97 33 45 31 85 27 55 75 28 42 80 63 93 11 12 20 40 97 72 46 58 92 16 65 58 46 74 98 27 29 68 13 14 98 55 70 29 31 12 93 53 61 44 76 84 84 22 78 19 70 53 19 71 44 56 82 91 61 27 29 25 97 41 64 60 0 37 55 50 42 48 40 37 26

39 66 13 76 83 11 79 62 98 18 71 10 31 84 91 11 44 80 52 49 59 76 42 19 53 86 57 54 12 64 62 63 99 69 86 56 78 42 29 35 83 12 54 64 19 52 96 87 18 97 59 83 39 11 93 90 97 26 20 71 12 22 37 71 48 38 66 65 89 77 91 72 44 0 44 33 42 10 73 94 27

55 95 77 81 62 67 36 32 32 40 29 34 12 81 28 89 44 75 81 95 46 57 60 74 29 69 57 73 19 83 64 89 18 40 88 36 42 46 82 73 78 67 70 16 51 45 52 45 26 82 53 78 56 42 70 73 54 83 63 82 14 96 92 48 33 95 92 75 17 93 50 60 19 66 0 49 63 61 70 66 67

61 22 36 86 61 39 24 50 44 92 86 67 59 26 71 47 37 10 41 52 73 76 71 69 91 99 65 95 32 50 84 58 98 23 54 32 36 29 75 22 82 39 76 91 78 13 50 63 89 38 51 25 72 43 90 66 31 32 98 51 71 59 17 63 57 73 34 51 99 56 88 23 96 78 80 0 94 13 97 78 44

85 32 61 83 77 26 88 29 31 38 30 47 30 27 13 60 64 55 70 73 58 98 62 52 91 67 10 44 71 78 66 82 78 59 13 40 41 89 43 40 79 90 53 40 31 61 93 46 59 81 37 43 44 75 92 65 50 51 92 62 87 33 55 96 45 86 47 89 38 78 16 89 26 97 69 26 0 64 71 73 98

33 32 76 95 17 57 47 48 90 94 15 42 60 38 76 87 17 78 61 15 14 21 40 85 49 14 45 65 56 58 20 36 12 70 12 67 79 40 93 59 52 35 21 21 43 54 59 78 40 44 83 78 55 18 21 21 77 21 91 88 39 12 69 36 42 97 56 26 42 54 47 28 36 13 37 17 79 0 83 73 67

21 28 72 30 75 89 86 80 97 86 38 32 89 49 82 65 56 42 94 96 22 68 54 85 16 41 76 90 39 53 43 96 15 85 50 11 41 56 11 80 89 22 41 37 67 54 88 28 13 71 65 84 32 17 81 97 17 74 20 46 32 53 61 30 52 97 89 42 43 29 62 11 61 38 43 85 39 37 0 12 63

24 34 11 24 19 81 47 61 68 49 33 51 78 55 56 58 27 53 59 87 87 11 30 62 22 23 75 61 81 33 95 29 15 90 46 30 61 17 16 46 58 11 62 22 11 16 46 32 19 65 38 80 84 60 26 97 25 69 61 57 54 67 16 89 35 20 45 93 60 86 17 48 50 13 57 56 90 59 80 0 30

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

58 80 38 27 74 77 18 69 73 19 94 61 32 41 31 17 11 25 74 14 88 10 45 77 90 30 42 52 41 24 56 41 37 80 70 12 78 60 58 45 61 62 74 26 85 13 51 87 77 90 92 21 25 80 45 52 43 31 53 50 28 89 10 14 71 84 32 73 36 98 70 81 73 35 51 15 94 19 51 14 0

Time Matrix

0 26 8 29 31 39 19 1 15 47 39 3 14 48 28 35 3 4 24 41 12 8 48 27 40 14 25 29 43 42 18 34 46 38 28 36 9 1 37 30 40 23 5 9 23 12 3 25 3 45 12 21 33 25 21 14 10 13 32 25 1 40 50 23 16 18 4 9 30 36 7 7 17 20 28 30 50 43 44 28 37

50 0 21 22 8 26 2 14 35 46 46 49 4 9 22 43 44 27 6 8 37 3 42 19 50 33 26 15 48 34 8 2 13 20 32 37 23 2 14 23 19 7 42 20 27 37 10 24 42 26 50 43 40 20 44 20 23 35 48 32 44 29 43 14 42 6 39 3 15 2 1 21 10 5 2 3 5 48 34 44 5

18 47 0 36 38 23 43 36 2 21 17 28 14 37 9 8 36 42 16 30 46 10 17 24 49 3 35 4 32 1 2 11 15 32 28 35 28 18 49 20 44 34 25 32 40 6 3 33 15 47 18 26 9 42 31 15 6 21 30 46 37 18 49 21 24 37 48 2 35 47 23 10 7 24 41 1 44 37 37 13 5

50 36 24 0 16 7 15 20 6 1 41 26 24 23 40 43 26 50 21 1 8 41 28 46 8 13 22 5 4 25 46 10 26 44 26 19 38 49 31 33 45 36 26 6 32 12 17 49 45 9 29 8 49 38 16 25 40 49 42 12 47 44 49 3 49 42 47 36 9 4 10 11 48 14 24 23 7 29 40 8 45

25 15 27 12 0 28 49 31 33 35 25 6 24 48 22 8 44 37 15 12 36 34 21 26 49 14 48 6 42 32 42 8 4 3 44 24 28 39 32 42 24 25 46 16 14 16 39 45 18 9 34 21 29 21 44 4 44 31 44 30 48 49 22 33 24 22 6 3 47 25 15 12 24 48 18 18 10 24 16 10 16

23 30 46 33 15 0 25 44 47 4 35 5 16 39 46 36 39 29 33 37 5 4 32 36 33 15 29 38 29 8 36 17 24 27 49 11 29 2 37 40 8 37 21 42 25 38 34 3 17 40 15 2 29 1 8 36 25 39 43 7 13 36 14 41 1 3 35 47 40 39 23 42 15 39 23 42 48 2 28 20 12

6 10 30 47 32 24 0 38 50 31 49 44 45 48 40 9 37 15 16 25 3 48 39 37 32 6 20 41 28 9 17 41 4 22 28 30 22 11 32 49 36 36 42 42 10 40 32 34 46 46 48 23 46 19 47 3 25 10 38 44 34 21 4 25 41 37 46 1 30 21 32 1 41 22 32 1 19 18 46 17 48

41 43 47 35 43 36 26 0 38 49 40 43 19 37 45 10 29 10 43 41 45 31 47 31 49 12 50 34 38 41 7 29 31 5 42 11 23 32 6 19 43 40 48 3 1 47 50 50 3 1 23 17 36 23 11 21 38 31 23 44 14 45 48 9 46 27 19 1 14 33 29 28 44 31 28 46 16 15 32 16 11

7 16 10 25 50 23 47 26 0 32 5 19 11 6 5 4 25 22 49 47 44 26 14 33 9 38 22 8 29 33 9 34 34 5 50 9 30 26 31 15 44 38 13 40 6 18 46 20 3 9 31 1 10 9 19 27 44 38 48 11 26 33 45 30 3 22 49 21 4 27 1 19 22 31 25 22 28 21 34 49 7

50 43 41 22 36 40 48 12 48 0 4 48 5 34 8 5 12 47 33 48 38 38 24 30 35 44 3 42 14 48 28 28 29 24 47 7 11 18 11 46 37 28 3 20 4 4 20 23 24 15 11 16 48 7 33 2 39 26 41 28 9 23 26 37 38 44 22 15 45 35 50 41 42 24 12 18 30 27 1 36 32

45 29 26 12 37 42 36 49 7 9 0 26 33 10 44 20 27 49 9 9 19 22 23 15 38 20 39 30 15 21 19 9 50 45 36 4 25 3 7 24 7 22 37 13 37 29 28 6 26 12 10 5 39 9 41 3 43 5 20 39 37 38 47 34 10 22 33 40 19 37 35 18 3 35 8 11 33 25 11 49 25

13 34 41 28 30 8 20 40 16 49 33 0 9 15 10 1 10 3 36 44 6 45 12 37 33 3 19 34 10 2 4 13 50 11 14 39 39 34 10 26 34 19 44 5 32 32 35 14 38 16 48 13 25 2 23 41 48 42 2 36 23 37 21 27 7 5 36 37 33 35 46 33 35 18 39 2 17 31 49 40 12

38 16 18 12 24 42 40 2 13 37 45 17 0 47 2 43 17 48 47 44 15 39 6 7 45 33 43 18 31 24 41 17 4 42 16 42 34 1 7 16 44 29 4 49 24 14 14 7 21 11 3 50 30 22 42 50 14 23 15 45 47 5 49 15 13 9 12 45 25 27 37 50 40 18 11 12 9 10 42 32 1

38 20 3 21 40 28 29 10 21 25 5 24 40 0 21 17 34 12 1 4 24 40 13 42 13 17 20 2 9 42 18 40 36 6 45 6 5 29 34 43 7 19 23 32 1 23 12 23 17 36 29 30 35 2 9 46 5 15 40 41 49 38 46 1 33 28 41 46 1 43 4 31 25 5 41 36 47 1 41 42 33

34 45 25 19 38 29 43 35 39 15 21 43 16 44 0 48 16 9 41 44 17 27 28 17 5 6 7 49 4 24 40 18 22 26 12 2 11 14 10 25 11 18 2 32 13 16 47 15 14 38 17 24 10 45 8 7 18 38 45 23 15 10 5 25 46 13 32 46 4 40 24 38 43 6 16 26 6 50 38 44 13

47 11 19 50 11 20 45 32 8 30 18 44 30 49 33 0 34 6 6 43 17 42 33 13 5 40 31 29 15 44 9 29 19 1 38 32 44 11 16 6 36 19 28 47 8 14 8 44 26 9 14 50 11 16 6 4 46 32 48 29 13 45 24 37 14 43 47 1 22 3 14 39 38 25 2 28 21 24 38 11 7

17 41 30 23 5 50 43 14 8 4 42 29 41 4 24 45 0 36 10 49 33 8 3 19 29 7 45 39 2 10 24 48 31 20 2 27 24 3 25 23 28 4 21 25 45 22 19 24 46 1 8 3 17 10 17 24 49 26 29 25 15 8 29 8 18 25 33 16 41 36 43 4 41 20 33 31 35 17 49 34 40

11 4 42 6 1 18 34 25 9 25 31 16 40 1 25 4 24 0 16 24 23 18 47 10 13 49 41 8 10 21 44 18 21 17 16 14 17 15 23 27 29 13 11 13 16 4 24 43 31 39 34 39 7 33 23 35 43 27 24 47 25 42 18 6 29 37 12 33 46 10 13 4 35 17 28 18 13 13 23 45 45

21 50 4 31 39 39 46 40 33 14 6 41 1 31 21 3 42 29 0 40 17 11 50 21 7 48 25 23 3 31 18 25 14 50 12 12 46 7 18 44 48 26 9 46 26 36 7 47 7 19 34 15 43 34 32 38 43 24 20 31 35 32 24 11 26 9 49 11 22 33 5 26 37 31 36 4 33 17 44 18 16

16 29 22 11 1 36 46 25 42 41 48 8 44 13 27 3 16 28 28 0 22 11 36 40 17 10 24 1 18 20 8 9 46 6 50 15 17 38 22 29 1 33 21 11 20 43 19 22 30 3 3 48 46 13 19 17 38 24 29 6 22 48 17 38 7 12 50 47 3 19 6 27 21 4 31 23 31 28 27 46 11

33 32 12 39 11 19 20 17 41 50 37 43 31 9 23 11 29 28 21 36 0 41 1 30 35 47 39 32 16 19 2 1 45 36 38 25 8 50 16 31 25 33 46 50 36 49 1 9 25 38 43 40 10 50 38 19 13 3 16 37 5 12 28 48 18 49 28 13 10 34 31 20 28 18 35 28 48 2 39 42 1

28 29 16 39 36 37 49 21 12 46 29 18 13 13 39 25 40 46 14 24 41 0 1 16 21 39 34 22 10 50 27 2 50 4 40 8 44 35 12 49 14 44 34 49 50 40 4 40 42 50 29 17 31 21 35 38 33 32 11 5 5 44 48 7 33 4 39 43 9 5 40 7 4 15 49 1 21 46 39 38 6

38 48 13 30 6 34 34 4 47 14 6 4 32 23 11 48 5 35 47 49 8 49 0 40 24 10 33 17 14 7 44 9 20 2 13 15 30 7 13 6 47 3 29 17 46 50 18 22 48 32 48 5 24 3 22 9 14 19 28 24 9 33 6 29 6 47 38 34 50 32 39 48 30 29 24 37 44 4 11 18 36

14 26 12 49 20 29 20 29 9 49 34 50 6 16 19 36 14 48 12 9 33 15 36 0 36 13 49 25 9 14 26 36 40 34 1 13 14 11 14 19 3 30 39 15 4 18 32 3 4 32 40 36 32 34 28 20 15 21 25 47 23 10 38 3 46 36 25 10 18 14 18 29 24 38 30 41 29 46 30 7 44

8 10 42 31 11 48 16 24 26 17 43 29 50 28 44 26 15 12 49 22 35 46 11 30 0 6 17 27 21 50 19 43 8 5 16 43 1 33 36 9 43 20 5 14 7 23 6 29 30 24 13 32 47 21 44 50 24 10 43 40 45 16 41 16 18 2 7 16 16 8 12 37 28 25 19 38 22 33 42 48 47

12 35 46 50 36 40 23 39 47 16 41 36 2 36 34 29 35 48 3 11 48 16 13 17 28 0 27 33 14 18 27 31 46 16 38 25 42 6 9 37 23 35 4 18 7 24 35 21 32 49 2 15 24 33 1 9 42 31 31 9 6 1 18 32 17 6 50 31 42 15 17 21 2 29 36 30 33 34 39 20 7

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

35 19 19 28 33 46 31 37 19 45 22 50 16 23 22 23 19 43 5 15 35 49 31 29 34 37 0 48 4 49 8 31 9 11 19 4 19 10 19 11 8 48 2 16 48 23 32 43 1 48 15 18 46 1 15 39 29 28 31 28 31 19 32 31 17 38 31 48 5 2 6 35 39 45 36 47 7 14 17 11 41

22 22 47 5 7 1 8 32 38 17 39 38 46 26 40 15 16 42 8 21 22 16 42 15 15 26 23 0 17 23 43 47 44 40 25 38 37 18 18 16 40 17 13 16 10 40 7 30 26 15 49 3 34 46 3 3 34 44 43 24 24 2 43 37 18 6 1 26 48 41 48 12 39 26 40 47 12 25 35 47 32

49 46 43 49 16 15 32 39 27 9 10 5 9 5 36 5 43 36 50 35 5 8 10 46 24 39 25 19 0 38 30 7 11 28 45 23 9 23 29 15 28 11 15 31 15 32 23 50 48 34 4 24 24 26 9 38 3 4 12 13 29 29 33 1 33 43 21 26 49 23 22 28 36 3 2 34 7 42 4 49 27

30 1 45 22 1 5 7 44 44 37 42 23 38 10 47 46 6 29 50 44 12 12 17 47 38 44 49 50 45 0 50 26 37 34 49 14 45 48 20 35 26 5 39 50 12 43 17 32 15 42 21 26 16 46 43 29 42 39 49 26 12 35 39 17 48 13 20 42 29 38 2 10 23 34 15 33 31 22 3 4 48

46 5 23 13 17 40 40 10 5 20 20 16 21 34 34 2 14 11 27 29 2 38 24 30 16 35 47 25 45 28 0 15 21 17 24 44 34 37 7 45 39 4 6 16 4 41 36 1 33 31 2 3 14 50 35 31 43 46 18 27 27 21 16 46 44 10 29 43 44 50 44 36 43 45 47 38 7 43 19 8 29

21 24 11 25 47 37 10 30 36 34 41 22 32 17 45 36 3 2 50 40 20 7 5 48 13 47 11 47 31 9 12 0 21 1 36 7 47 4 32 48 5 39 12 21 17 24 25 48 27 29 46 23 26 6 44 23 28 14 23 18 23 1 49 2 11 23 30 33 41 47 12 34 20 22 37 36 39 15 22 11 25

47 6 33 25 47 10 44 45 45 12 46 41 3 44 27 26 20 33 5 44 24 16 23 9 46 11 31 39 41 11 17 8 0 2 20 38 42 34 14 46 35 28 28 18 40 39 10 29 14 9 5 4 12 47 31 14 24 44 39 3 18 49 8 2 26 11 2 8 28 43 11 35 50 3 48 32 38 44 39 32 11

1 16 5 39 40 23 34 49 11 35 19 29 33 9 8 48 10 43 6 45 27 46 47 2 7 31 34 18 46 22 44 6 39 0 26 11 44 44 20 8 16 39 49 35 29 11 8 2 44 48 46 47 19 36 17 3 10 41 23 39 33 5 3 18 19 4 41 44 42 49 37 16 48 23 21 33 12 5 2 20 27

45 41 48 7 10 36 10 39 37 3 39 8 6 6 17 37 7 31 13 6 29 43 46 49 44 49 4 9 13 2 24 26 27 37 0 10 4 15 40 30 7 8 43 12 40 44 30 44 11 32 13 17 22 40 28 27 28 35 45 45 42 14 2 49 15 50 16 1 37 25 31 41 33 45 41 16 24 33 50 23 45

30 2 2 11 41 4 13 27 29 38 1 18 44 33 37 31 42 13 3 41 9 45 43 30 3 41 34 13 20 28 50 26 50 29 17 0 9 20 13 2 11 26 19 21 15 31 33 44 49 12 17 13 42 29 43 38 24 31 25 7 40 43 50 47 19 37 12 23 16 33 10 47 28 3 10 21 6 13 50 9 31

10 44 28 22 10 13 45 46 40 23 12 50 14 6 13 4 4 19 38 45 16 18 50 29 35 31 40 36 18 19 44 43 49 7 17 18 0 3 13 18 46 14 8 33 29 46 5 8 15 23 19 5 38 47 45 7 5 21 26 19 32 11 7 15 3 46 36 17 15 11 27 27 48 22 27 23 42 1 32 28 14

5 18 33 1 36 19 37 38 6 15 26 6 26 46 10 33 7 17 48 2 38 43 35 14 50 30 13 29 20 33 36 7 21 45 13 31 11 0 5 46 14 16 22 32 10 41 26 18 1 45 7 17 13 29 7 28 8 44 49 15 45 44 50 26 43 36 27 5 19 35 24 46 7 42 20 2 17 4 30 33 11

29 31 13 27 14 9 49 48 40 8 8 18 12 34 10 27 29 50 4 16 28 4 46 11 31 50 44 14 45 28 37 34 30 11 36 2 4 12 0 22 44 34 21 34 3 39 6 1 5 10 13 33 45 4 37 48 10 28 8 47 13 50 6 41 47 33 20 16 39 44 49 13 38 33 18 18 48 31 37 17 32

50 24 48 44 12 27 24 42 24 12 44 32 4 17 5 2 7 3 10 44 46 9 45 50 25 14 2 2 31 42 36 19 36 46 32 47 14 23 33 0 37 11 42 19 2 5 8 32 50 45 46 50 46 3 47 12 32 6 3 50 47 43 40 19 26 3 1 9 3 1 10 37 17 30 30 21 8 3 29 18 9

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

41 20 20 14 20 44 8 44 34 48 14 16 45 7 18 26 24 18 20 26 30 36 48 9 43 8 39 3 42 48 5 20 12 31 12 7 37 16 41 33 0 38 38 37 30 27 22 33 3 39 14 50 38 45 31 16 26 36 49 31 23 50 9 13 15 37 29 38 6 4 42 15 9 6 9 46 30 18 5 30 41

11 15 42 50 24 24 14 14 43 41 46 33 16 11 28 15 7 22 10 42 10 42 1 17 25 8 37 21 44 22 20 39 25 30 29 6 26 1 1 46 16 0 31 29 41 16 15 43 28 31 40 20 44 10 4 32 23 8 38 17 18 7 1 41 9 44 49 5 3 19 18 36 8 8 4 48 16 34 11 32 46

9 45 50 7 50 41 15 46 18 49 23 44 21 17 49 12 23 48 37 8 3 34 31 22 41 48 8 42 28 31 32 33 6 12 23 26 9 21 38 34 9 31 0 35 39 48 35 29 22 41 16 45 38 24 14 37 7 6 46 48 14 36 18 5 15 47 46 31 31 11 37 39 10 14 49 2 17 48 21 3 25

15 48 14 11 10 12 25 39 34 31 7 33 34 47 25 6 12 10 22 49 29 2 20 3 49 42 29 39 33 48 43 1 31 1 25 45 11 50 7 27 7 15 37 0 44 31 30 21 32 48 10 45 4 49 39 8 31 30 22 41 21 30 50 16 38 4 11 10 29 24 37 43 9 44 46 24 48 23 39 11 17

43 22 7 17 16 23 42 6 28 9 12 21 1 41 4 37 3 46 30 42 15 45 49 5 5 29 24 36 14 30 43 33 50 36 48 2 11 43 29 8 8 30 7 16 0 14 46 13 30 2 45 32 1 45 13 29 43 42 24 44 41 17 38 9 22 39 45 21 16 44 15 29 3 20 38 3 30 36 1 28 2

16 1 37 5 35 10 12 45 24 16 22 40 19 24 42 9 37 36 41 49 31 41 34 9 17 23 14 34 17 3 19 43 28 39 29 48 32 27 12 17 20 6 36 10 12 0 16 12 46 45 36 33 32 45 43 46 22 32 2 3 33 40 45 22 17 31 15 39 40 26 19 6 27 4 20 45 49 5 42 21 14

15 20 13 9 44 33 14 43 34 48 39 24 26 27 17 31 2 49 6 38 5 1 16 24 45 49 2 19 40 41 42 31 28 6 6 49 16 21 14 43 36 49 46 40 47 27 0 25 31 36 42 44 41 4 27 12 32 4 1 8 21 49 34 3 18 31 22 47 23 13 29 44 14 21 12 47 18 47 39 43 26

20 37 44 2 24 5 37 8 46 41 44 45 49 43 24 13 9 6 32 2 9 16 13 13 5 27 1 9 17 6 18 13 2 24 7 31 20 29 29 14 46 26 28 41 48 2 36 0 27 27 27 38 33 16 24 37 33 33 6 30 2 33 48 8 2 29 35 41 37 45 35 30 3 49 42 3 14 29 35 15 45

19 50 40 39 8 45 26 2 24 13 45 38 41 17 7 12 44 25 29 50 1 9 42 13 39 41 20 20 39 19 1 25 16 6 21 43 40 26 47 41 9 10 11 2 15 41 25 28 0 28 47 40 42 31 35 12 33 17 18 33 40 18 3 9 37 43 17 3 8 12 29 12 38 1 17 47 49 3 20 45 32

44 25 42 16 35 2 14 42 16 36 36 19 24 33 49 11 27 21 22 13 50 18 45 45 22 29 49 40 47 30 10 50 16 50 12 44 37 26 20 28 35 5 20 26 8 13 33 7 5 0 5 5 42 21 41 27 4 1 37 10 46 50 4 45 44 35 39 43 42 38 43 13 20 21 50 33 30 18 29 31 15

8 38 3 2 14 40 8 9 35 21 27 37 10 10 17 24 16 12 4 15 48 31 39 43 14 28 41 28 20 16 24 5 43 5 43 13 3 33 22 32 27 35 24 38 43 2 29 5 8 31 0 5 18 25 35 38 7 23 47 42 25 48 33 2 21 36 4 38 26 35 43 3 31 26 23 30 41 37 33 36 24

46 21 46 16 29 32 39 8 42 23 46 42 46 28 13 31 2 33 16 5 46 42 41 32 40 17 44 11 46 21 11 37 12 17 31 12 42 32 22 40 27 3 7 16 22 12 44 48 48 41 44 0 41 2 42 13 49 20 35 50 16 45 46 37 41 23 31 21 42 44 34 29 25 28 48 1 20 33 23 17 32

4 23 37 35 8 5 44 14 6 38 19 31 48 32 30 23 40 40 46 15 13 32 19 48 15 12 24 25 11 7 25 46 23 35 15 12 10 42 44 43 40 40 4 35 27 33 50 19 10 17 2 39 0 30 38 10 26 21 24 38 9 4 27 2 50 11 39 15 48 50 36 23 30 42 4 35 35 40 29 46 20

8 4 18 23 1 29 6 19 30 44 19 11 38 45 6 7 48 22 40 27 24 15 23 17 14 3 1 4 13 36 34 40 36 35 47 32 42 20 15 14 27 11 23 23 37 34 45 1 7 47 36 20 42 0 22 6 34 47 45 27 17 44 39 7 4 5 35 34 11 29 43 24 30 45 24 46 26 32 8 35 42

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

21 43 14 44 26 7 33 26 1 5 39 17 38 19 27 22 31 15 8 10 4 50 31 33 10 41 41 14 31 37 27 31 46 44 11 29 34 16 1 45 7 8 38 45 29 11 12 39 10 21 41 34 10 34 0 8 6 21 11 47 20 50 20 7 2 33 44 21 25 5 38 34 36 22 40 49 14 27 6 43 35

12 44 1 28 25 29 10 41 31 8 26 22 25 8 20 28 15 2 41 27 37 11 22 30 16 45 18 9 12 43 9 32 5 10 47 21 7 11 17 6 45 10 33 8 48 31 4 45 7 35 24 14 30 28 21 0 23 10 8 12 15 38 28 49 18 40 21 39 19 26 35 29 5 16 28 26 11 49 11 5 11

50 37 44 35 18 10 49 40 49 26 2 28 42 2 44 19 23 23 35 14 24 24 29 15 29 31 4 9 31 39 18 24 47 34 26 36 14 27 29 10 22 45 39 39 18 39 37 29 43 32 37 19 28 50 13 38 0 29 11 16 6 46 1 31 5 20 16 35 46 48 25 45 23 10 13 30 12 34 35 7 10

41 28 46 35 40 1 37 11 4 11 13 45 8 46 12 22 12 21 30 7 10 20 5 29 4 37 1 24 28 35 25 37 37 21 5 11 14 8 26 38 17 34 25 43 12 14 3 12 22 47 31 44 38 27 34 34 27 0 44 10 1 30 45 20 50 42 23 11 36 38 3 36 23 49 6 17 40 49 1 39 37

29 49 35 7 10 25 44 6 35 18 38 20 23 36 50 32 32 42 38 20 34 18 15 35 48 40 30 44 45 46 36 5 44 32 13 31 47 2 37 24 25 30 48 2 45 34 21 23 45 39 9 5 7 46 38 26 23 38 0 50 44 23 40 8 18 48 20 11 19 49 22 38 33 18 29 15 30 49 43 45 7

19 4 31 26 37 22 33 9 42 48 8 26 45 9 46 31 29 11 48 16 47 43 33 15 3 11 4 44 16 13 9 1 32 46 38 40 48 28 22 18 2 12 11 22 43 41 28 38 32 37 13 22 43 36 22 27 47 21 3 0 26 43 40 14 45 11 50 41 48 16 50 8 13 29 16 6 11 6 47 34 28

14 38 26 23 13 28 16 28 24 35 36 1 20 9 9 22 48 38 25 20 39 29 46 10 45 36 17 1 10 1 11 10 27 32 4 1 11 33 25 32 17 45 22 28 18 21 32 13 50 24 36 23 3 7 29 20 45 27 18 17 0 38 4 17 2 29 24 10 4 6 39 31 32 21 43 27 19 41 7 37 14

28 3 33 14 33 7 12 7 9 16 48 17 41 16 36 12 43 6 30 21 41 23 21 2 27 37 27 32 30 26 38 29 13 28 23 6 41 37 46 8 35 31 25 21 14 21 17 14 41 15 1 25 38 2 13 30 10 5 20 8 22 0 26 50 44 46 38 8 27 43 29 38 24 28 50 37 48 38 18 24 6

32 36 10 15 41 44 1 25 6 24 37 14 31 43 11 35 19 15 25 46 5 4 45 49 15 7 6 42 41 33 27 38 45 19 4 48 30 43 36 1 24 45 1 1 4 42 33 12 25 45 39 23 11 39 21 7 12 44 45 43 38 47 0 30 22 2 35 1 27 17 39 18 37 47 40 7 45 28 5 47 39

41 11 34 49 50 22 2 12 43 21 43 36 27 31 24 28 28 9 27 40 7 5 35 9 46 3 23 19 1 36 17 46 20 24 47 11 18 11 24 15 5 39 15 18 18 10 43 50 28 25 7 28 10 44 21 15 8 6 10 5 1 29 5 0 11 33 50 13 18 13 13 39 11 8 17 11 32 17 45 11 43

31 19 19 35 30 18 33 9 23 23 9 4 15 41 50 47 38 37 7 33 29 48 12 11 46 45 26 15 2 13 49 16 28 36 15 29 47 17 23 19 8 14 44 30 32 41 6 43 32 9 26 14 24 8 16 14 39 9 15 15 40 26 5 33 0 46 37 41 27 10 2 27 41 24 2 46 12 36 15 33 19

12 24 26 26 35 6 20 26 12 43 20 25 3 16 9 29 2 2 39 27 5 39 24 14 26 37 44 5 6 30 2 32 13 14 13 5 32 29 48 47 7 39 46 37 25 3 46 1 44 7 37 39 15 2 46 10 23 46 24 12 32 16 15 48 28 0 10 32 38 9 23 6 25 5 49 38 16 10 29 2 35

35 27 23 46 33 14 37 22 4 50 9 34 19 7 14 11 43 16 44 2 8 28 22 25 5 40 40 23 22 38 25 18 6 11 15 47 22 22 18 48 37 47 50 14 27 50 17 38 39 25 18 14 37 9 1 45 10 38 17 37 36 42 20 6 14 9 0 7 3 37 4 45 38 25 46 41 1 41 24 9 1

32 12 17 44 31 28 44 36 44 26 24 12 30 10 3 41 16 42 7 35 34 40 40 31 33 12 5 42 12 15 38 29 16 39 29 37 43 7 34 34 14 37 48 23 50 46 38 5 50 35 13 20 38 45 4 49 44 31 41 18 4 15 22 20 5 37 48 0 48 21 44 37 4 38 33 37 23 10 6 24 18

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

25 2 25 29 11 6 35 1 47 17 42 34 49 31 8 6 23 25 11 36 40 11 11 10 46 13 1 13 42 39 35 44 24 29 39 24 23 17 17 20 40 39 30 21 50 45 8 21 25 31 31 24 1 4 48 38 30 22 50 38 31 9 5 29 18 15 35 38 0 18 36 34 18 2 10 17 39 5 3 24 37

5 49 27 7 38 43 4 38 6 50 11 37 19 28 45 41 36 17 4 29 33 26 19 41 22 32 17 29 31 12 37 10 50 40 4 47 48 40 28 24 13 1 24 34 9 28 23 6 50 43 46 2 24 39 15 13 11 41 3 41 40 37 15 14 43 13 38 46 18 0 47 19 4 35 20 27 15 16 1 41 40

19 6 29 9 38 3 27 46 6 36 47 24 32 30 18 12 18 8 50 6 40 22 27 2 15 9 47 48 23 15 37 19 40 21 12 19 30 29 7 48 22 38 15 36 49 11 19 8 6 25 41 39 14 49 2 18 28 13 15 7 7 7 14 1 16 20 14 16 45 10 0 44 27 41 35 44 32 12 11 26 25

37 21 17 40 30 47 24 24 7 9 14 25 34 1 36 1 30 3 35 15 40 38 7 3 42 12 29 30 44 30 19 39 29 17 19 20 8 24 27 12 21 47 45 43 33 1 43 39 22 9 26 12 9 17 36 24 18 18 27 24 35 10 50 2 40 50 4 10 9 38 12 0 16 8 40 44 10 30 6 50 14

3 21 46 40 11 43 5 19 7 13 35 41 13 16 36 9 2 38 12 1 45 24 45 26 25 32 11 6 3 6 41 39 36 49 10 20 2 29 10 23 26 2 37 27 36 37 34 30 10 27 6 26 16 47 8 4 21 44 35 28 7 47 18 10 24 50 47 21 8 2 29 42 0 35 1 50 14 20 39 45 42

14 38 39 35 50 23 28 23 49 35 37 16 34 28 46 26 22 43 3 40 8 38 21 19 19 50 24 6 44 38 13 36 1 30 27 31 20 48 1 5 8 41 2 47 7 14 25 8 32 50 2 24 18 17 49 6 18 37 22 11 50 35 47 48 20 49 37 29 10 22 4 47 2 0 28 37 7 35 39 41 2

41 31 23 4 21 28 23 36 4 28 1 38 4 16 28 46 32 11 46 6 4 4 45 30 50 27 16 27 5 13 39 38 43 7 46 46 44 36 30 1 42 21 29 41 24 2 8 30 12 40 24 36 30 23 18 24 41 33 40 33 22 25 39 36 38 17 49 35 4 1 45 18 44 41 0 5 18 36 38 29 18

50 20 2 23 30 31 21 40 10 28 4 17 34 12 25 42 28 43 24 39 32 47 41 17 21 11 10 24 29 9 50 24 5 25 1 38 31 50 46 41 2 35 18 14 18 44 3 32 45 20 44 25 16 8 24 18 15 13 19 26 29 3 18 16 40 4 45 39 40 3 22 33 1 25 25 0 25 48 7 20 38

48 30 14 24 35 3 50 5 33 39 34 13 4 6 22 44 36 36 39 22 33 4 42 14 12 14 38 19 8 38 18 46 41 5 3 3 49 47 5 20 20 9 24 39 20 44 33 22 10 50 36 17 45 31 32 28 34 26 35 37 12 3 5 4 41 35 29 12 36 34 28 39 20 49 8 15 0 45 3 18 29

30 8 11 18 28 4 6 1 14 24 29 37 49 28 44 21 43 26 3 10 32 18 50 8 36 25 32 26 24 36 6 44 31 18 28 38 7 43 22 17 15 19 43 23 49 40 13 12 35 8 38 20 21 6 18 41 17 42 21 37 9 19 15 21 20 36 6 19 34 24 16 44 37 47 43 38 9 0 44 44 37

26 16 32 31 34 50 2 50 8 46 12 50 32 29 33 41 42 9 42 7 6 44 29 29 1 25 10 15 2 8 24 35 26 41 32 20 29 6 5 37 20 40 33 43 3 30 19 46 32 24 30 41 2 9 27 1 6 9 47 13 49 48 23 12 45 16 1 44 46 34 34 47 5 9 15 23 10 20 0 49 10

22 20 19 37 32 21 17 6 37 14 8 50 9 8 45 12 48 37 9 48 1 28 19 50 26 1 27 25 17 40 32 46 39 21 44 8 40 24 27 23 31 3 20 21 40 43 37 36 32 46 13 25 20 16 33 47 47 31 9 28 31 9 22 36 13 31 29 24 39 21 17 42 37 46 14 20 33 14 41 0 22

33 2 30 8 4 22 21 18 46 16 42 23 24 5 15 1 18 48 5 46 41 7 41 50 40 22 16 40 14 9 47 45 37 38 42 30 13 12 20 18 37 4 27 20 50 8 11 7 22 44 31 14 14 28 33 39 36 5 39 35 13 35 30 35 4 30 32 14 17 20 46 33 14 39 39 31 42 29 38 40 0

Base Timestay Matrix

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

4 3 10 7 7 7 6 2 8 8 2 8 5 5 1 2 1 10 9 8 1 9 9 3 4 8 5 5 10 3 8 10 2 9 4 9 6 3 7 6 1 2 5 7 7 6 9 4 9 8 7 5 6 3 6 10 7 9 8 7 3 8 10 6 5 2 10 8 5 8 2 2 5 4 3 9 5 5 9 5

Excess Timestay Matrix

7 7 1 7 2 7 6 10 4 7 9 6 9 3 6 5 8 4 3 5 3 5 7 10 3 4 1 5 2 4 5 10 10 2 1 7 7 9 1 7 8 8 6 9 6 4 7 3 6 6 5 7 8 4 6 7 4 3 2 8 6 3 6 8 4 1 5 6 5 6 3 6 7 7 5 2 4 10 9 3

Base Demand Matrix

23 5 5 24 9 25 17 6 22 19 19 10 14 17 8 10 14 16 11 25 19 3 13 12 9 6 7 21 6 13 17 6 5 4 10 16 9 11 16 12 15 9 22 22 18 3 6 19 20 4 11 1 4 16 16 11 7 3 4 2 9 19 7 15 21 14 6 19 14 1 14 10 21 15 17 24 20 4 7 14

Excess Demand Matrix

21 12 1 20 16 14 19 15 8 1 19 6 9 12 19 2 15 13 4 25 21 5 11 9 15 13 6 12 14 22 5 10 17 3 8 15 3 17 22 15 22 15 5 22 20 19 12 17 23 4 10 23 17 18 14 16 3 23 10 14 14 17 18 14 16 12 21 8 20 25 11 1 15 9 19 20 6 22 3 25

Expense city Matrix

75 89 77 32 79 87 70 25 49 21 20 5 71 3 87 36 65 53 64 57 60 49 23 33 3 48 30 15 82 57 90 99 47 2 35 13 68 25 49 73 34 30 38 66 43 44 13 32 96 77 40 83 87 84 14 25 17 30 59 68 97 77 12 6 55 94 51 65 35 81 36 92 90 15 52 67 90 92 51 35

Earning city Matrix

186 231 265 106 300 278 277 105 212 132 143 163 229 284 261 171 253 291 225 139 182 228 243 125 137 126 106 147 187 110 235 275 288 266 288 251 156 260 273 109 129 119 151 255 178 201 253 289 141 132 194 124 135 154 233 140 202 269 234 193 162 265 153 128 293 167 123 281 232 278 297 213 134 128 102 269 299 222 210 282

Output:

In each iteration, the first 20 values are the P_Best values of 20 particles and last value is the G_Best value. Next line contains the Profit, Number of vehicles and total time of the corresponding G_Best value.

12.07 12.22 13.12 12.94 11.52 12.81 11.54 12.45 12.19 11.80 11.49 12.12 12.48 11.65 11.10 11.76 11.38 12.98 11.99 12.51   -->> 13.12

Profit: 4519.0 no. of vehicle: 57 total time: 4342

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

12.07 12.96 13.12 12.94 11.93 12.81 12.31 12.45 12.19 12.06 13.20 12.73 12.48 11.91 13.09 12.51 12.78 12.98 11.99 12.51   -->> 13.20

Profit: 4538.0 no. of vehicle: 53 total time: 4469

12.20 12.96 13.12 13.05 12.07 12.81 12.80 12.45 12.85 12.45 13.20 13.03 12.48 12.97 13.09 12.51 12.78 12.98 12.00 12.64   -->> 13.20

Profit: 4081.0 no. of vehicle: 60 total time: 4484

12.75 12.96 13.12 13.05 12.07 12.81 12.80 12.45 12.85 12.45 13.20 13.03 12.48 12.97 13.36 12.51 12.78 12.98 13.27 12.64   -->> 13.36

Profit: 4740.0 no. of vehicle: 57 total time: 4563

12.75 12.96 13.12 13.05 12.24 12.81 12.80 12.45 12.92 12.45 13.20 13.03 12.48 13.04 13.36 12.51 12.78 12.98 13.27 12.70   -->> 13.36

Profit: 4114.0 no. of vehicle: 57 total time: 4323

12.75 12.96 13.12 13.05 12.24 12.81 12.80 12.79 12.92 12.45 13.20 13.19 13.11 13.04 13.36 12.52 12.81 12.98 13.27 12.99   -->> 13.36

Profit: 4313.0 no. of vehicle: 58 total time: 4619

12.75 12.96 13.12 13.05 12.64 12.81 12.80 12.80 12.92 12.45 13.20 13.19 13.11 13.04 13.36 13.30 12.81 12.98 13.27 12.99   -->> 13.36

Profit: 4171.0 no. of vehicle: 60 total time: 4709

13.06 12.96 13.12 13.33 12.66 12.81 12.80 12.80 12.92 12.45 13.20 13.19 13.11 13.04 13.36 13.30 12.81 12.98 13.27 12.99   -->> 13.36

Profit: 4348.0 no. of vehicle: 57 total time: 4547

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

13.06 12.96 13.12 13.33 12.66 12.81 12.80 12.80 13.16 12.45 13.20 13.19 13.11 13.04 13.36 13.30 12.81 13.20 13.27 12.99   -->> 13.36

Profit: 4289.0 no. of vehicle: 56 total time: 4279

13.56 12.96 13.12 13.33 12.66 12.81 12.80 12.80 13.16 12.45 13.20 13.20 13.11 13.04 13.36 13.30 12.81 13.20 13.27 12.99   -->> 13.56

Profit: 4696.0 no. of vehicle: 55 total time: 4393

13.56 12.96 13.12 13.33 12.66 12.81 12.80 12.96 13.16 12.45 13.20 13.20 13.11 13.04 13.36 13.30 12.81 13.20 13.27 12.99   -->> 13.56

Profit: 4206.0 no. of vehicle: 59 total time: 4535

13.56 12.96 13.46 13.33 12.66 12.81 12.80 13.31 13.16 12.71 13.20 13.20 13.11 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 3917.0 no. of vehicle: 58 total time: 4316

13.56 12.96 13.46 13.33 12.66 12.81 12.80 13.31 13.16 13.14 13.20 13.20 13.24 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4275.0 no. of vehicle: 58 total time: 4406

13.56 12.96 13.46 13.33 12.71 12.81 12.80 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4215.0 no. of vehicle: 57 total time: 4378

13.56 12.96 13.46 13.33 12.71 12.99 13.11 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4419.0 no. of vehicle: 54 total time: 4427

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

13.56 12.96 13.46 13.33 12.71 13.17 13.11 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4517.0 no. of vehicle: 57 total time: 4475

13.56 12.96 13.46 13.33 12.71 13.17 13.11 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4443.0 no. of vehicle: 56 total time: 4394

13.56 12.96 13.46 13.33 13.46 13.17 13.11 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4487.0 no. of vehicle: 58 total time: 4427

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4419.0 no. of vehicle: 59 total time: 4499

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.16 13.14 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4504.0 no. of vehicle: 56 total time: 4557

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.16 13.45 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4333.0 no. of vehicle: 56 total time: 4529

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.16 13.45 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4191.0 no. of vehicle: 56 total time: 4460

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4250.0 no. of vehicle: 57 total time: 4359

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4530.0 no. of vehicle: 56 total time: 4306

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4377.0 no. of vehicle: 58 total time: 4320

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.20 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4395.0 no. of vehicle: 57 total time: 4285

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4337.0 no. of vehicle: 57 total time: 4340

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.38 13.04 13.36 13.30 13.12 13.20 13.27 12.99   -->> 13.56

Profit: 4337.0 no. of vehicle: 57 total time: 4340

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.38 13.04 13.36 13.30 13.12 13.26 13.27 12.99   -->> 13.56

Profit: 4398.0 no. of vehicle: 58 total time: 4309

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.38 13.04 13.36 13.30 13.12 13.26 13.27 12.99   -->> 13.56

Profit: 4436.0 no. of vehicle: 57 total time: 4251

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.38 13.04 13.36 13.30 13.12 13.26 13.27 12.99   -->> 13.56

Profit: 4436.0 no. of vehicle: 57 total time: 4251

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.53 13.04 13.36 13.30 13.12 13.26 13.27 12.99   -->> 13.56

Profit: 4436.0 no. of vehicle: 57 total time: 4251

13.56 12.96 13.46 13.33 13.46 13.17 13.17 13.31 13.42 13.45 13.27 13.20 13.62 13.04 13.36 13.30 13.12 13.27 13.27 12.99   -->> 13.62

Profit: 4771.0 no. of vehicle: 54 total time: 4525

13.56 12.96 13.46 13.33 13.46 13.44 13.17 13.31 13.42 13.45 13.27 13.20 13.62 13.04 13.36 13.30 13.12 13.27 13.34 12.99   -->> 13.62

Profit: 4077.0 no. of vehicle: 58 total time: 4456

13.56 12.96 13.46 13.33 13.46 13.44 13.17 13.31 13.42 13.45 13.27 13.20 13.62 13.04 13.36 13.30 13.12 13.27 13.34 12.99   -->> 13.62

Profit: 4189.0 no. of vehicle: 56 total time: 4463

13.56 12.96 13.46 13.33 13.46 13.44 13.17 13.31 13.42 13.45 13.27 13.20 13.62 13.04 13.36 13.30 13.32 13.27 13.34 12.99   -->> 13.62

Profit: 4199.0 no. of vehicle: 59 total time: 4546

13.56 12.96 13.46 13.33 13.46 13.44 13.17 13.31 13.42 13.45 13.27 13.20 13.62 13.04 13.36 13.30 13.32 13.27 13.34 12.99 -->> 13.62

Profit: 3959.0 no. of vehicle: 58 total time: 4511

13.56 12.96 13.46 13.33 13.46 13.44 13.17 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.27 13.34 12.99 -->> 13.62

Profit: 4152.0 no. of vehicle: 59 total time: 4381

13.56 12.96 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.27 13.34 13.78 -->> 13.78

Profit: 4799.0 no. of vehicle: 56 total time: 4363

13.56 12.96 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.27 13.34 13.78 -->> 13.78

Profit: 4047.0 no. of vehicle: 59 total time: 4455

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.27 13.34 13.78 -->> 13.78

Profit: 3882.0 no. of vehicle: 60 total time: 4534

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4333.0 no. of vehicle: 56 total time: 4500

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4081.0 no. of vehicle: 58 total time: 4611

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4165.0 no. of vehicle: 60 total time: 4446

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4026.0 no. of vehicle: 59 total time: 4366

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4072.0 no. of vehicle: 57 total time: 4321

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4151.0 no. of vehicle: 58 total time: 4215

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4143.0 no. of vehicle: 58 total time: 4230

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.20 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4143.0 no. of vehicle: 58 total time: 4230

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78 -->> 13.78

Profit: 4143.0 no. of vehicle: 58 total time: 4230

13.56 13.68 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.78

Profit: 4245.0 no. of vehicle: 58 total time: 4455

13.56 13.92 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.92

Profit: 4813.0 no. of vehicle: 55 total time: 4318

13.56 13.92 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.92

Profit: 4258.0 no. of vehicle: 57 total time: 4443

13.56 13.92 13.46 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.92

Profit: 4472.0 no. of vehicle: 58 total time: 4505

13.56 13.92 13.70 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.92

Profit: 3986.0 no. of vehicle: 59 total time: 4479

13.56 13.92 13.70 13.33 13.46 13.44 13.51 13.31 13.42 13.45 13.27 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.92

Profit: 4102.0 no. of vehicle: 58 total time: 4405

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.34 13.78   -->> 13.92

Profit: 4459.0 no. of vehicle: 57 total time: 4551

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4331.0 no. of vehicle: 57 total time: 4320

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.34 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4116.0 no. of vehicle: 60 total time: 4626

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4430.0 no. of vehicle: 56 total time: 4468

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4479.0 no. of vehicle: 57 total time: 4450

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4396.0 no. of vehicle: 57 total time: 4500

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4384.0 no. of vehicle: 56 total time: 4606

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4560.0 no. of vehicle: 56 total time: 4540

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

**13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32
13.76 13.60 13.78   -->> 13.92**

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78 -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

13.56 13.92 13.70 13.33 13.46 13.85 13.51 13.31 13.42 13.45 13.35 13.21 13.62 13.52 13.36 13.30 13.32 13.76 13.60 13.78   -->> 13.92

Profit: 4425.0 no. of vehicle: 58 total time: 4530

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Profit: 4502.0 no. of vehicle: 57 total time: 4477

GRAPH FOR FITNESS FUNCTION-

F=(PROFIT^{α})/(NO_OF_VEHICLE^{β}* TOTAL_TIME$^{¥}$) WHERE α=0.8, β=0.4, ¥=0.2

Here, Profit is given the highest priority followed by number of vehicle and total time while evaluating the fitness value of a particle.
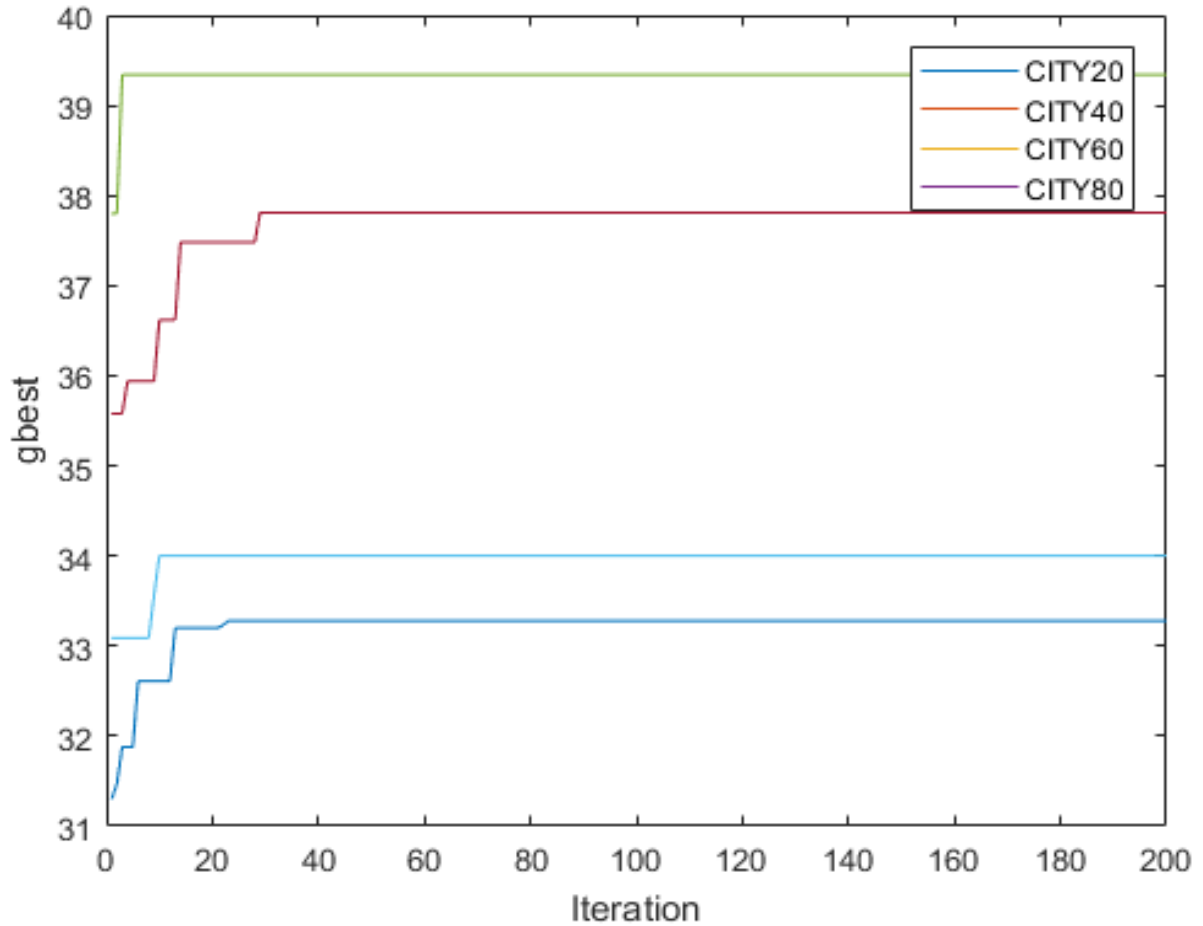
Fig: 4

This graph shows the change of G_Best values for 200 iterations where number of particles is 20 and cities taken are 20, 40, 60 and 80 for the above fitness function.

MULTI-OBJECTIVE PROFIT MAXIMIZATION VEHICLE ROUTING PROBLEM USING PARTICLE SWARM OPTIMIZATION

GRAPH FOR FITNESS FUNCTION-

F=(PROFIT^{α})/(NO_OF_VEHICLE^{β}* TOTAL_TIME$^{¥}$) WHERE α=0.8, β=0.2, ¥=0.4

Here, Profit is given the highest priority followed by total time and number of vehicle while evaluating the fitness value of a particle.
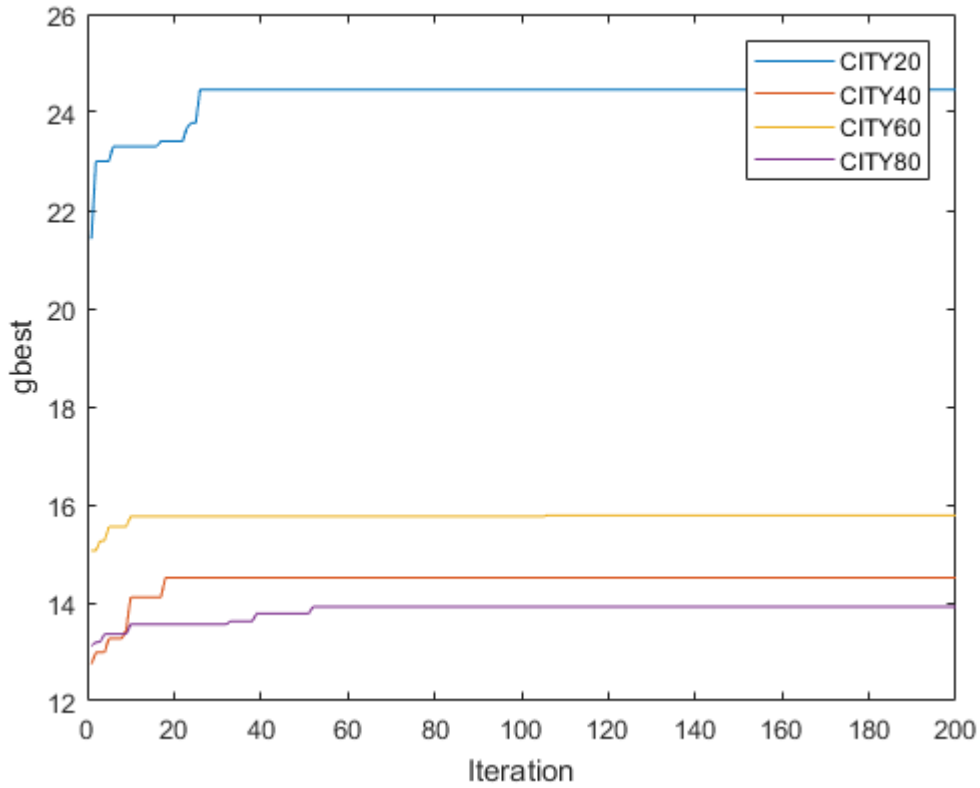
Fig: 5

This graph shows the change of G_Best values for 200 iterations where number of particles is 20 and cities taken are 20, 40, 60 and 80 for the above fitness function.

CONCLUSION

Here, we have implemented PARTICLE SWARM OPTIMIZATION algorithm to find the optimal solution of Vehicle Routing Problem. Our objective was to find the route which gives us the maximum profit, while keeping the tour time within a limit. As the number of particles and iterations increases the chances of getting the optimal solution also increases. The most significant contribution of this work is our interpretation of the VRP as a computational approach. Finally, its performance is very good.

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5. Swarm Intelligence in Multiple and Many Objectives Optimization: A Survey and Topical Study on EEG Signal Analysis by B.S.P. Mishra, Satchidanand Dehuri and Sung-Bae Cho

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APPENDIX

/*Input Cost Matrix*/
/*Cost_matrix class*/

```java
import java.util.Random;
import java.io.*;
public class Cost_matrix
{
        int cost[][];
        int n;
        public Cost_matrix(int n)
        {
                this.n=n;
        cost=new int[n+1][n+1];
        }

        void populateM()
        {
                try{
    BufferedReader in = null;
     int rows = 0;
     int row=0,i;
     in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO code\\City_20\\Cost_20.txt"));
     String line = null;
     while((line=in.readLine()) !=null) {
          String [] tokens = line.split(" ");
          for (int j=0; j<n+1;j++) {
             cost[row][j] = Integer.parseInt(tokens[j]);

          }
          row++;
      }
     if (in!=null) in.close();
   }
    catch (IOException e)
  {
   System.out.println("IOException : " + e);
  }

        }
        }

}
```
/*Input Time Matrix*/
/*Time_matrix class*/
```java
import java.io.*;
import java.util.Random;
public class Time_matrix
{
```

```java
        int time[][];
        int n;
        public Time_matrix(int n)
        {
                this.n=n;
        time=new int[n+1][n+1];
        }

        void populateT()
        {
                try{
       BufferedReader in = null;
        int rows = 0;
        int row=0,i;
        in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Time_Travel_20.txt"));
        String line = null;
        while((line=in.readLine()) !=null) {
            String [] tokens = line.split(" ");
            for (int j=0; j<n+1;j++) {
                time[row][j] = Integer.parseInt(tokens[j]);
            }
            row++;
        }
        if (in!=null) in.close();
     }
      catch (IOException e)
   {
    System.out.println("IOException : " + e);
   }
        }

}

/*Input Time stay in each city*/
/*Timestay class*/
import java.util.Random;
import java.io.*;
public class TimeStay
{
        int[] t,bt,et;
        int n,tt;//tt=total stay time
        public TimeStay(int city,int tour)
        {
                n=city;
                tt=tour/4;
                t=new int[city+1];
                bt=new int[city+1];
                et=new int[city+1];
        }
        void populateTS()
        {
```

```
                    try{
        BufferedReader in = null;
          int rows = 0;
          int row=0,i;
          in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Base_Time_Stay_20.txt"));
         String line = null;
         while((line=in.readLine()) !=null) {
               String [] tokens = line.split(" ");
               for (int j=1; j<=n;j++) {
                  bt[j] = Integer.parseInt(tokens[j-1]);
               }
         }
         if (in!=null) in.close();
         in=null;
         in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Excess_Time_Stay_20.txt"));
         line = null;
         while((line=in.readLine()) !=null) {
               String [] tokens = line.split(" ");
               for (int j=1; j<=n;j++) {
                  et[j] = Integer.parseInt(tokens[j-1]);
               }
         }
         if (in!=null) in.close();
      }
       catch (IOException e)
                   {
                           System.out.println("IOException : " + e);
                   }
    finally{
                   System.out.println();
                   System.out.println("Base TimeStay::");
                   for(int i=1;i<=n;i++)
                   {
                           System.out.print(bt[i]+" ");
                   }
                   System.out.println();
System.out.println("Excess TimeStay::");
                   for(int i=1;i<=n;i++)
                   {
                           System.out.print(et[i]+" ");
                   }
System.out.println();
                   System.out.println("Total TimeStay::");
                   for(int i=1;i<=n;i++)
                   {
                           t[i]=bt[i]+et[i];
                           System.out.print(t[i]+" ");
                   }
         }
         }
```

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```
        }

/*Input Profit in each City*/
/*Profit class*/
import java.util.Random;
import java.io.*;
public class Profit
{
        int[] ear,exp,pr;
        int n,tpr;
        public Profit(int city)
        {
                n=city;
                tpr=0;
                ear=new int[city+1];
                exp=new int[city+1];
                pr=new int[city+1];
        }
        void populatePr()
        {
                try{
        BufferedReader in = null;
        int rows = 0;
        int row=0,i;
        in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Earning_City_20.txt"));
        String line = null;
        while((line=in.readLine()) !=null) {
            String [] tokens = line.split(" ");
            for (int j=1; j<=n;j++) {
                ear[j] = Integer.parseInt(tokens[j-1]);

            }
        }
        if (in!=null) in.close();
        in=null;
        in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Expense_City_20.txt"));
        line = null;
        while((line=in.readLine()) !=null) {
            String [] tokens = line.split(" ");
            for (int j=1; j<=n;j++) {
                exp[j] = Integer.parseInt(tokens[j-1]);
            }
        }
        if (in!=null) in.close();
    }
    catch (IOException e)
            {
                    System.out.println("IOException : " + e);
            }
            finally{
```

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```
                System.out.println("Earning of each city::");
            for(int i=1;i<=n;i++)
            {
                System.out.print(ear[i]+" ");
            }
            System.out.println();
System.out.println("Expense of each city::");
            for(int i=1;i<=n;i++)
            {
                System.out.print(exp[i]+" ");
            }
System.out.println();
            System.out.println("Net profit of each city::");
            for(int i=1;i<=n;i++)
            {
                pr[i]=ear[i]-exp[i];
                tpr=tpr+pr[i];
                System.out.print(pr[i]+" ");
            }
            System.out.println();
            System.out.println("Total profit from all cities:: "+tpr);
        }
        }
}

/*Input Demand In Each City*/
/*Demand class*/
import java.util.Random;
import java.io.*;
public class Demand
{
        int[] d,bd,ed;
        int n,vC;
        public Demand(int city,int vCap)
        {
                n=city;
                vC=vCap;
                d=new int[city+1];
                bd=new int[city+1];
                ed=new int[city+1];
        }
        void populateD()
        {
                        try{
        BufferedReader in = null;
         int rows = 0;
         int row=0,i;
         in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Base_Demand_20.txt"));
         String line = null;
         while((line=in.readLine()) !=null) {
             String [] tokens = line.split(" ");
```

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```
                for (int j=1; j<=n;j++) {
                    bd[j] = Integer.parseInt(tokens[j-1]);
                }
            }
        if (in!=null) in.close();
        in=null;
        in = new BufferedReader(new FileReader("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Excess_Demand_20.txt"));
        line = null;
        while((line=in.readLine()) !=null) {
                String [] tokens = line.split(" ");
                for (int j=1; j<=n;j++) {
                    ed[j] = Integer.parseInt(tokens[j-1]);
                }
            }
        if (in!=null) in.close();
    }
     catch (IOException e)
                {
                        System.out.println("IOException : " + e);
                }
                finally{
                System.out.println();
                System.out.println("Base Demand::");
                for(int i=1;i<=n;i++)
                {
                        System.out.print(bd[i]+" ");
                }
                System.out.println();
                System.out.println("Excess Demand::");
                for(int i=1;i<=n;i++)
                {
                        System.out.print(ed[i]+" ");
                }
System.out.println();
                System.out.println("Total Demand::");
                for(int i=1;i<=n;i++)
                {
                        d[i]=bd[i]+ed[i];
                        System.out.print(d[i]+" ");
                }
        }
        }
}


/*Input Particle*/
/*Particle class*/
import java.util.Random;
import java.util.Collections;
public class Particle
{
```

```java
        int[][] pArr;
        int p,n;
        public Particle(int n,int p)
        {
                pArr=new int[p+1][n+1];
                this.p=p;
                this.n=n;
        }
        void populateP()
        {
                Random rand = new Random();
                int a;
                for(int i=1;i<=p;i++)
                {
                        for(int j=1;j<=n;j++)
                        {
                                a=rand.nextInt(n)+1;
                                pArr[i][j]=a;
                                for (int k = 1; k < j; k++)
                                {
                        if (pArr[i][j] == pArr[i][k])
                        {
                        j--;
                        break;
                }
                 }
                        }
                }
        }
}


/*Input Velocity*/
/*Velocity class*/
import java.util.Random;
import java.util.Collections;
public class Velocity
{
        double[][] vArr;
        int p,n;
        public Velocity(int n,int p)
        {
                vArr=new double[p+1][n+1];
                this.p=p;
                this.n=n;
        }
        void populateV()
        {
                Random rand = new Random();
                double a;
                for(int i=1;i<=p;i++)
```

```
                    {
                            for(int j=1;j<=n;j++)
                            {
                                    a=rand.nextDouble();
                                    a= (a*5.2) + (0.2*0.9);
                                    if(a>n || a<0)
                                    {
                                            j--;
                                            break;
                                    }
                                    vArr[i][j]=a;
                            }

                    }
}
```

```
/*Creating Sub-routes for Particles Checking Vehicle Capacity*/
/*Sweep class*/
public class Sweep
{
        double[] fitness,profit;
        int[] store_route,vehicle,temp,temp1;
        double alpha=0.8,beta=0.4,gama=0.2;
        void fit(int p,int[][] cost,int vCap,int[] dmnd,int city,int[][] part,int[][] time,int max_time,int[] ts,int tpr)
        {
                Time_constraint tc=new Time_constraint(p);
                store_route=new int[city+1];
                vehicle=new int[p+1];
                for(int i=1;i<=p;i++)
                        vehicle[i]=0;
                fitness=new double[p+1];
                for(int i=1;i<=p;i++)
                        fitness[i]=0;
                temp=new int[p+1];
                temp1=new int[p+1];
                profit=new double[p+1];
                for(int i=1;i<=p;i++)
                        profit[i]=0;
                for(int i =1;i<=p;i++)
                {
                        int c=0,d=0,tot=0,a=0,s=0;
                        for(int j=1;j<=city;j++)
                        {

                                a=part[i][j];
                                d=d+dmnd[a];
                                if(d>vCap )
                                {

        fitness[i]=fitness[i]+tc.check_constraint(store_route,time,max_time,0,s,cost,ts,i,vehicle);
```

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```
                                        for(int k=0;k<s;k++)
                                        store_route[k]=0;
                                        s=0;
                                        c=0;
                                        d=dmnd[a];
                            }
                            store_route[s++]=a;
                            if(j==city)
                            {
fitness[i]=fitness[i]+tc.check_constraint(store_route,time,max_time,0,s,cost,ts,i,vehicle);
                            }
                            c=a;
                       }
                }
          temp=tc.getVehicle();
          temp1=tc.getTime();
           for(int i=1;i<=p;i++)
           {
                    double z=tpr-fitness[i];
                    profit[i]=z;
           z=(Math.pow(profit[i],alpha)/(Math.pow(temp[i],beta)*Math.pow(temp1[i],gama)));
                    fitness[i]=z;
           }

     }
}


/*Checking Tour Time for each Sub-routes*/
/*Time_Constraint class*/
import java.lang.*;

class Time_constraint
{
        int[] tVehicle,fTime;
        public Time_constraint(int p)
        {
                tVehicle=new int[p+1];
                fTime=new int[p+1];
                for(int i=1;i<=p;i++)
                fTime[i]=0;
        }

        int check_constraint(int[] store_route,int[][] time,int max_time,int low,int s,int[][] costM,int[] ts,int tv,int[]
vehicle)
        {
                int cost=0,i,tot=0,d=0,a=0,v=0;
                temp[0]=0;
                int z= s-low;
                for(i=low;i<s;i++)
                {
```

```
                              a=time[d][store_route[i]];
                              tot=tot+a;
                              tot=tot+ts[store_route[i]];
                              d=store_route[i];
                      }
                      tot=tot+time[d][0];
                      if(tot<=max_time || z==1)
                      {
                              cost=cost+costM[0][store_route[0]];
                              for(i=1;i<s;i++)
                              {
                                      cost=cost+costM[store_route[i-1]][store_route[i]];
                              }
                              cost=cost+costM[store_route[i-1]][0];
                              vehicle[tv]=vehicle[tv]+(++v);
                              tVehicle[tv]=vehicle[tv];
                              fTime[tv]=fTime[tv]+tot;
                      }
                      else
                      {
                              int high=s;
                              s=(int)Math.ceil((high+low)/2);
              check_constraint(store_route,time,max_time,low,s,costM,ts,tv,vehicle);
              check_constraint(store_route,time,max_time,s,high,costM,ts,tv,vehicle);
                      }
                      return cost;
              }

              int[] getVehicle()
              {
                      return tVehicle;
              }
              int[] getTime()
              {
                      return fTime;
              }
}


/*Calulating P_best Values of each Particle*/
/*P_best class*/

import java.text.DecimalFormat;
public class Pbest
{
              double[] p_best;
              int[][] part_config;
              DecimalFormat f = new DecimalFormat("##.00");
              public Pbest(int p,int n)
              {
                      p_best=new double[p+1];
                      part_config=new int [p+1][n+1];
```

```
                    for(int i=1; i<=p; i++)
                            p_best[i]=Integer.MIN_VALUE;

        }
        public Pbest(int p,int n, double[] fit,double[] pb)
        {
                p_best=new double[p+1];
                part_config=new int[p+1][n+1];        }
        public double[] populatePbest(int p,int n,double[] fit,double[] pb,int[][] pArr)
        {
                for(int i=1;i<=p;i++)
                {
                        if(fit[i]>pb[i])
                        {
                                p_best[i]=fit[i];
                                for(int j=1;j<=p;j++)
                                {
                                        for(int k=1;k<=n;k++)
                                                part_config[j][k]=pArr[j][k];

                                }
                        }
                        else
                        {
                                p_best[i]=pb[i];
                        }
                }
                return p_best;
        }
}


/*Calculating G_Best Values*/
/*G_best class*/
import java.text.DecimalFormat;
public class Gbest
{
        double g_best;
        int loc;
        int[] gConfig;
        DecimalFormat f = new DecimalFormat("##.00");
        public double minGbest(double[] p_best,int n,int[][] part_config,double[] profit,int[] temp,int[] temp1)
        {
                gConfig=new int[n+1];
                double min=Integer.MIN_VALUE;
                for(int i=1;i<p_best.length;i++)
                {
                        if(min<p_best[i])
                        {
                                min=p_best[i];
                                loc=i;
                        }
```

```
                }
                g_best=min;

                for(int i=1;i<=n;i++)
                        gConfig[i]=part_config[loc][i];

                return g_best;
        }
}


/*Updating Velocity Of Each Particles*/
/*Velo_update class*/

class Velo_update
{
        double[][] velo;
        int part,city;

        public Velo_update(int p,int n)
        {
                velo=new double[p+1][n+1];
                part=p;
                city=n;
        }
        void update(int p, int n, int[][] pConfig,int[][] pArr,int[] gConfig,double[][] vel)
        {
                double res;
                for(int i=1;i<=p;i++)
                {
                        for(int j=1;j<=n;j++)
                        {
                                velo[i][j]=vel[i][j];
                        }
                }
                for(int i=1;i<=p;i++)
                {
                        for(int j=1;j<=n;j++)
                        {
                                res=0.6*velo[i][j]+0.2*0.3*(pConfig[i][j]-pArr[i][j])+0.2*0.5 *(gConfig[j]-
pArr[i][j]);
                                velo[i][j]=res;
                        }
                }
        }

}

/*Updating Particles*/
/*Part_update class*/

class Part_update
```

```
{
        int pUpdate[][],city,p;
        public Part_update(int p,int n)
        {
                pUpdate=new int[p+1][n+1];
                this.p=p;
                city=n;
        }
        void update(double[][] velo,int[][] part)
        {
                double temp[][]=new double[p+1][city+1];
                for(int i=1;i<=p;i++)
                {
                        for(int j=1;j<=city;j++)
                        {
                                temp[i][j]=velo[i][j]+part[i][j];
                                if(temp[i][j]>city)
                                        temp[i][j]=city;
                                if(temp[i][j]<0)
                                        temp[i][j]=0;
                        }
                }

                System.out.println();
                int loc=1,c=0;
                double temp1=Integer.MAX_VALUE;
                for(int i=1;i<=p;i++)
                {
                        c=0;
                        for(int k=1;k<=city;k++)
                        {
                                for(int j=1;j<=city;j++)
                                {

                                        if(temp[i][j]<temp1)
                                        {

                                                loc=j;
                                                temp1=temp[i][j];
                                        }
                                        if(temp[i][j]==temp1)
                                        {
                                                if(velo[i][j]<velo[i][loc]){
                                                        loc=j;
                                                        temp1=temp[i][j];
                                                }
                                        }
                                }
                                pUpdate[i][loc]=++c;
                                temp[i][loc]=Integer.MAX_VALUE;
                                temp1=Integer.MAX_VALUE;
                        }
```

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```
                    }
            }
}

/*Main Class */
/*Pso Class*/

import java.text.DecimalFormat;
import java.lang.*;
import java.io.*;
public class Pso
{
        public static void main(String[] args)
        {
                try{
                        DecimalFormat f = new DecimalFormat("##.00");
                        BufferedWriter out;
                        out = new BufferedWriter(new FileWriter("C:\\Users\\User\\Desktop\\PSO
code\\City_20\\Output_20.txt"));
                        String str,str1,str2,str3;
                        double res1,res2[];
                        int vCap=30;
                        int nParticle=20;
                        int city=20;
                        int totalTourTime=100;
                        System.out.println("vehile capacity: "+vCap+" no. of paticle "+nParticle+" no. of cities "+city+"
totao tour time "+totalTourTime);
                        Cost_matrix cm=new Cost_matrix(city);
                        cm.populateM();
                        cm.print();
                        Time_matrix tm=new Time_matrix(city);
                        tm.populateT();
                        tm.print();
                        TimeStay ts=new TimeStay(city,totalTourTime);
                        ts.populateTS();
                        Profit pro=new Profit(city);
                        pro.populatePr();
                        Particle p=new Particle(city,nParticle);
                        p.populateP();
                        Velocity v=new Velocity(city,nParticle);
                        v.populateV();
                        System.out.println("Demand");
                        Demand dd=new Demand(city,vCap);
                        dd.populateD();
                        System.out.println();
                        System.out.println("velocity and Particle taken as random");
                        System.out.println();
                        Sweep sw=new Sweep();
                        sw.fit(nParticle,cm.cost,vCap,dd.d,city,p.pArr,tm.time,totalTourTime,ts.t,pro.tpr);
                        System.out.println("pbest and gbest are aas follows:");
                        System.out.println();
                        Pbest pb1=new Pbest(nParticle,city);
```

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```
                Pbest pb2=new Pbest(nParticle,city,sw.fitness,pb1.p_best);
                res2=pb2.populatePbest(nParticle,city,sw.fitness,pb1.p_best,p.pArr);
                Gbest gb=new Gbest();
                res1=gb.minGbest(pb2.p_best,city,pb2.part_config,sw.profit,sw.temp,sw.temp1);
                Velo_update vel=new Velo_update(nParticle,city);
                vel.update(nParticle,city,pb2.part_config,p.pArr,gb.gConfig,v.vArr);
                Part_update pu=new Part_update(nParticle,city);
                pu.update(vel.velo,p.pArr);
                for(int i=1;i<=200;i++)
                {
                        System.out.println();
                        System.out.println("loop:"+i);*/
                        for(int k=1;k<=nParticle;k++)
                        {
                                str=String.valueOf(f.format(res2[k]));
                        out.write(str+"  ");
                        }
                        str=String.valueOf(f.format(res1));
                        str1=String.valueOf(sw.profit[gb.loc]);
                        str2=String.valueOf(sw.temp[gb.loc]);
                        str3=String.valueOf(sw.temp1[gb.loc]);
        out.write("  -->> "+str);
        out.newLine();
        out.write("Profit: "+str1+" no. of vehicle: "+str2+" total time: "+str3);
        out.newLine();
                        sw.fit(nParticle,cm.cost,vCap,dd.d,city,pu.pUpdate,tm.time,totalTourTime,ts.t,pro.tpr);
                        res2=pb2.populatePbest(nParticle,city,sw.fitness,pb2.p_best,pu.pUpdate);
                        res1=gb.minGbest(pb2.p_best,city,pb2.part_config,sw.profit,sw.temp,sw.temp1);
                        vel.update(nParticle,city,pb2.part_config,p.pArr,gb.gConfig,vel.velo);
                        pu.update(vel.velo,pu.pUpdate);
                }
                for(int k=1;k<=nParticle;k++)
                        {
                                str=String.valueOf(f.format(res2[k]));
                        out.write(str+"  ");
                        }
                str=String.valueOf(f.format(res1));
        str1=String.valueOf(sw.profit[gb.loc]);
                str2=String.valueOf(sw.temp[gb.loc]);
                str3=String.valueOf(sw.temp1[gb.loc]);
        out.write("  -->> "+str);
        out.newLine();
        out.write("Profit: "+str1+" no. of vehicle: "+str2+" total time: "+str3);
        out.newLine();
                out.close();
        }
         catch (IOException e)
{
 System.out.println("IOException : " + e);
}
        }
```