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A **TSP model for medical equipment or product distribution to different hospitals to minimize cost using Genetic Algorithm**

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Abstract
Distribution of medical products and equipment is currently a major problem for hospital management systems. Within a certain amount of time, medical equipment ought to be accessible at several hospitals. If not, the hospital sector will implode. In an emergency, they are unable to offer the patients alternative services. Therefore, things ought to be delivered on time. In order to provide hospitals with modern equipment, supply must be swift and sophisticated. Significant challenges in the last ten years have included creating a novel mathematical model and applying various soft-computing techniques to optimize the cost (travel cost). These have required a deeper comprehension of the mathematical structure and the distribution of medical equipment among various hospitals. Here a salesman or a medical van starts journey from a depot and visits hospitals/service points and comes back to the depot at the end of journey. A soft computing genetic algorithm will be used to solve the mathematical model of medical equipment distribution to a set number of hospitals in a two-dimensional Traveling Salesman Problem (TSP) to determine the best itinerary with the lowest possible trip expenses.
Keywords: *Medical equipment distribution, Travel cost minimization, Tour time constraint, 2D TSP, Genetic Algorithm*

I. Introduction

1.1. Motivation

The medical and health care management and industry in West Bengal (WB) provides the study's context. Historically, the WB Government's Medical and Health Department was in charge of providing medical care until the late 2010s. Reports from hired consultants, such as the Plan of Action (2011–15)[1] from the Health and Family Welfare Department of WB, have drawn notable attention to concerns such the provision of medical services, equipment, and products in hospitals. The goal and objective of the organization was to place special attention on the creation and upkeep of service standards in hospitals and other healthcare facilities. One of the key goals was to provide everyone with necessary health care that was high-quality, inexpensive, sustainable, and accessible within five years. Focusing on the impoverished, elderly, mothers, children, and residents of underdeveloped areas was another objective.

The following issues are critical for the health department[1] to develop as focus areas: i) Establish and meet fundamental service criteria for healthcare in the public sector. ii) Decongest hospitals for tertiary care Reducing patient out-of-pocket expenses; iv) Achieving clinical service package norms for each tier of institutions as per the Indian Public Health Standard 2010; v) Establishing the 'hub and spoke model of care' with an appropriate referral chain, a transport system, and another

[1]https://shorturl.at/vDSX2

satellite centre concept vi) Modernize and enhance the infrastructure, especially the diagnostic facilities vii) Guarantee a free or heavily discounted supply of medications and other important medical supplies viii) Raise the bar for non-clinical facilities and services provided to patients and their families. Optimizing Kolkata's surrounding secondary care facilities that are underutilized ix) Launch administrative changes for health care, such as the establishment of seven new health districts. x) Create more modern facilities in district and subdivisional hospitals, such as ICUs/ITUs, different burn units (BU), trauma care units (TCU), and blood banking (BB) facilities. xi) Create newborn care units on the Purulia model in secondary and primary care facilities. xii) Boost adolescent care services, particularly for girls; xiii) Create more sub-centers in accordance with the 2011 census; xiv) Introduce cashless delivery (CD) and free transportation at all service points/hospitals xv) Create a functional Comprehensive Emergency Obstetric Care Centre (CEOCC) within a 25-kilometer radius and a functional Basic Emergency Obstetric Care Centre (BEOCC) within a 6-kilometer radius both. xvi) Create a network of public health laboratories at the district and state levels xvii) Establish a regional centre (RC) for disease control (DC) xviii) Gather resources from within and beyond the government and look into public-private partnerships for the state's urban health program xix) Connect with the current municipal health framework and initiatives xxi) Expand the reach of health service delivery (HSD) through ASHA and other different mechanisms; xxi) Establish a specific project management unit (PMU) that includes the deployment of Mobile Medical Units(MMU) for Jangalmahal, a delta region like Sundarbans, tea gardens, forest hamlets of North Bengal (NB), and coal mine areas (CMA). xxii) Create ten new medical colleges gradually; xxiii) Create two AIIMS-like institutions; xxiii) Create new nursing and paramedical education schools and colleges; xxiv) Investigate the PPP model to establish super-specialty facilities(SSF) and new medical colleges(MCs); xxv) Connect districts with MCs for supportive supervision and so forth.

The WB Department of Health and Family Welfare assumes responsibility for the overall supervision of all hospitals that receive public funding, while the Department of Health handles primary community health care, including community dentistry and medical clinics, maternal and child health services, and so forth.

Medical devices are used both as parts of medical apparatuses and in biological systems. Glass, metals, ceramics, polymers, medical equipment made from animals, and so forth are a few typical types of medical equipment. These are utilized in companies, hospitals, institutions, laboratories for medical research, etc. These locations are thought of as hospitals. Here, a salesperson arranges a trip, leaves from a storage facility, visits each of the other hospitals precisely once, then returns to the storage facility for the least amount of money.

In this study, I focus on the construction of such a comprehensive modeling framework, illustrating its intended helpful uses with small-scale numerical examples. It is my sincere belief that a mathematical approach of this kind will significantly contribute to well-informed decision making on the management of medical care provided overall.

The suggested models to solving 2D Traveling Salesman Problems (TSPs) makes use of the heuristic known as the Genetic solution (GA) [11].

- The novel aspect of the current investigation is the development of original routing models for trip cost minimization.
- Two model formulation trade-offs are discussed in this inquiry.
- 2D TSP is formulated mathematically with time constraint.
- The price of the trip is stated.
- The travel time of the trip is calculated.
- A Genetic Algorithm is suggested in the suggested algorithm.
- GA optimizes the discrete routing strategy.
- Discrete variables are the properties that make a chromosome.
- Travel expenses are kept to a minimum
- The optimal path is chosen to display the managerial decisions.

This paper is organized and structured as follows. Section 1 gives an introduction, while Section 1.1 provides a motivation, and Section 1.2 provides a brief assessment of the literature survey. In Section 2, the mathematical model is presented here. Section 3 goes into detail about the Genetic algorithm. Then the numerical experiments are shown in Section 4. A summary of the discussion can be found in Section 5. Section 6 presents the model's conclusion in the end.

1.2. Literature review

Chu and Chu [2] offered a modeling framework(MF) to schedule the supply and demand matching(SDM) of the hospital beds that are available in Hong Kong for the next years up until 2006. Planning concerns pertaining to hospital locations(HL) and service allocations(SA) —which encompass both the relocation of existing services and the assignment of new ones—are managed by it. Here, the structure of such an extensive modeling framework is emphasized, and samples of its planned applications in the form of small-scale numerical examples are provided. A summary of the existing literature is included in this paper by Feillet et al. [5], which suggests a taxonomy of TSPs with profits.

Liu, Ran, et al.'s work [10] deals with a vehicle scheduling issue that arises in home health care logistics(HHCL). It deals with the transportation of medications and medical equipment from a hospital to patients' homes, the delivery of specialized medications from a home care business, and the collection of biopsies and unused medications and equipment from patients. The said problem can be viewed as a specific vehicle routing problem(VRP) with simultaneous delivery and pickup(SDP) and time windows(TW), with four different sorts of demands like: delivery from a depot to a patient(D2P), delivery from a hospital to a patient(H2P), pickup from a patient to a depot(P2D), and pickup from a patient to a medical lab(P2ML). A logistical issue with home health care that arises in France is examined. It relates to the delivery and pickup of materials between the pharmacies, patients, hospitals, and laboratories. A proposed genetic algorithm(GA) incorporates both local search and permutation chromosomes. It is designed to perform a tabu search with route re-optimization and route assignment features.

Researchers Lee, Jongsung, et al. [11] create a mixed integer program(MIP) and suggest a variation of a big neighborhood search algorithm with several improvement methods in order to simulate the crucial production and delivery challenge. They carry out a number of computational tests to show how successful the suggested strategy is. When the strategy is used in a case study, it demonstrates that production and delivery can be improved in terms of both time and cost. A issue of modeling and defining the manufacturing and delivery of nuclear medicine is done. A model for mixed integer programming is created. It is suggested to use improvement algorithms with a big neighborhood algorithm. Computational outcomes, along with a case study, demonstrate the effectiveness of the strategy.

According to Nagata and Soler [13], one of the most important combinatorial optimization(CO) challenges is the asymmetric traveling salesman problems (ATSPs). They demonstrate how to use GA to directly or indirectly address a variety of real-world problems.

An overview of the traveling salesman problem, together with applications, formulations, and ways to solving it, is provided by Matai et al. [7]. Additionally, a study of many TSP formulations using integer programming was produced by Orman and Williams [9].

Little et al. [6] suggest a "branch and bound" method for solving the traveling salesman issue. The set of all tours (possible solutions) is divided into successively smaller subsets via the process of branching. The maximum number of tours within each subset is calculated.

Using a permutation of n integers, the Chatterjee et al. [1] group introduced a new GA that can be directly utilized to estimate global optimal solutions to TSP. A study on pickup and delivery TSP with first-in-first-out (FIFO) loading was conducted by Erdog ņan et al. [4]. This study focuses on a particular version of TSP: pick-up and delivery. This version requires that loading and unloading be done in a FIFO fashion. It gives an integer programming version of the problem. Five operators for improving a potential solution are also detailed, as well as two heuristics that make use of these operators: an iterated local search algorithm and a probabilistic tabu search method.

The aforementioned cases and my research have inspired me to make observations and uncover the gaps in the literature about the use of a meta-heuristic GA to solve a 2DTSP model for the distribution of medical products and equipment in order to save travel expenses for various hospitals.

Table 1: Variable, parameter description, and decision variable explanation for many models.

Variable	**Description**
V	Set of cities/hospitals
E	Set of edges/roads
N	Number of cities/hospitals
$(x_1, x_2, \cdots, x_N, x_1)$	A tour of salesman, where x_1= depot
X_i	Fitness value for a solution
p_i	Probability for a solution
q_i	Cumulative probability for each solution X_i
T	Total travel time
T_{max}	Maximum allowable time
Z_{TC}	Minimum travel cost
For 2D TSP	

k, l	Indices
x_{kl}	when salesman visit from the k-th hospital/service point/city to l-th hospital/service point/city then = 1, otherwise = 0
c_{kl}	Travel cost from k^{th} to l^{th} hospital/service point/city
x_{kl}	Decision Variables

II. Model formulation

Figure 1 provides a pictorial depiction view for 2DTSP.

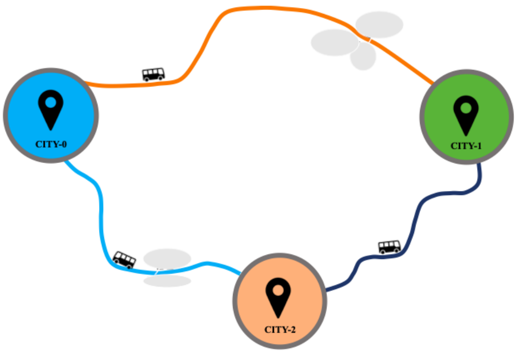

Figure 1: A diagram illustrating the suggested model 2D TSP

2.1 Nomenclature for different symbols

Table 1 provides a summary of common notations.

2.1 Model-A: Classical TSP

The vertex set V = 1, 2,⋯, N, and the edge set E are represented by graphs in the 2DTSP model. For salespeople in N cities, travel must be inexpensive. A salesperson leaves from one of the source city/depot, passes through each of the remaining cities/hospitals/service points precisely once and then comes back to the depot. Travel expenses are decided by c_{kl}, and the sequence in which the cities are visited is specified by x_{kl}. In this instance, the model might be expressed as MIP mathematically as follows (Dantzig et al. [3]):

$$Determine x_{kl}, where k = 1,2,3,\ldots,N; l = 1,2,3,\ldots,N$$

$$to minimize Z_{TC} = \sum_{k=1}^{N}\sum_{l=1}^{N} x_{kl} + c_{kl} \ldots\ldots(1)$$

$$subject to = \sum_{k=1}^{N} x_{kl} = 1; l = 1,2,3,\ldots,N$$

$$\sum_{l=1}^{N} x_{kl} = 1; k = 1,2,3,\ldots,N \ldots\ldots(2)$$

$$\sum_{k\in p}\sum_{l\in p} x_{kl} \leq |P| - 1, \forall p \subset V; x_{kl} \in 0,1 \ldots\ldots(3)$$

$$To minimize Z_{TC} = \sum_{k=1}^{N-1} C_{x_k,x_{k+1}} + c_{x_N,x_1} \ldots\ldots(4)$$

If salesman's travels from the k^{th} hospital/city to the l^{th} city/hospital, then $x_{kl} = 1$; otherwise, $x_{kl} = 0$, and P is the set of cities.

Let $(x_1, x_2, \cdots, x_N, x_1)$ represents a salesperson's tour.

Where $x_k \in \{1, 2, \cdots, N\}$ for $k = 1, 2, \cdots, N$ and all x_k's are distinct. The above mentioned model is simplified as follows:
Determine a salesman/distributor's tour $(x_1, x_2, \cdots, x_N, x_1)$.

2.2 Model-B: Proposed 2D TSP to minimize travel costs

$$MinZ_{TC} = \underbrace{\sum_{i=1}^{N-1} c(x_{(k)(l)}) * dis(x_{(k)(l)}) + c(x_{(N)(1)}) * dis(x_{(N)(1)})}_{TravelCost} \ldots\ldots (5)$$

$$subject\ to T = \underbrace{\sum_{i=1}^{N-1} t(x_{kl}) + t(x_{(N)(1)})}_{TravelTime} \ldots\ldots (6)$$

with constraints 2 and 3.

2.3 Model-C: Proposed 2D TSP to minimize travel costs under tour time constraints

$$MinZ_{TC} = \underbrace{\sum_{i=1}^{N-1} c(x_{(k)(l)}) * dis(x_{(k)(l)}) + c(x_{(N)(1)}) * dis(x_{(N)(1)})}_{TravelCost} \ldots\ldots (7)$$

$$subject\ to T = \underbrace{\sum_{i=1}^{N-1} t(x_{kl}) + t(x_{(N)(1)})}_{TravelTime} \ldots\ldots (8)$$

$$T \leq T_{max} \ldots\ldots (9)$$

and with constraints 2 and 3.
$Here T_{max} is the maximum tour time.$

III. Methodology: Genetic Algorithm

The Genetic process generates a finite number of salesman's paths or tours, together with automobile routes between hospitals/service points/nodes/cities, at the start of the proposed process, allowing salesmen to go from source city to destination city. Random Mutations, Cyclic Crossovers, and Roulette Wheel Selections are combined in Genetic Algorithms. The suggested GA and its algorithms, 1, 2, 3, and 4, are shown below in the order in which they were constructed. The following Figure 2 shows the GA flowchart.

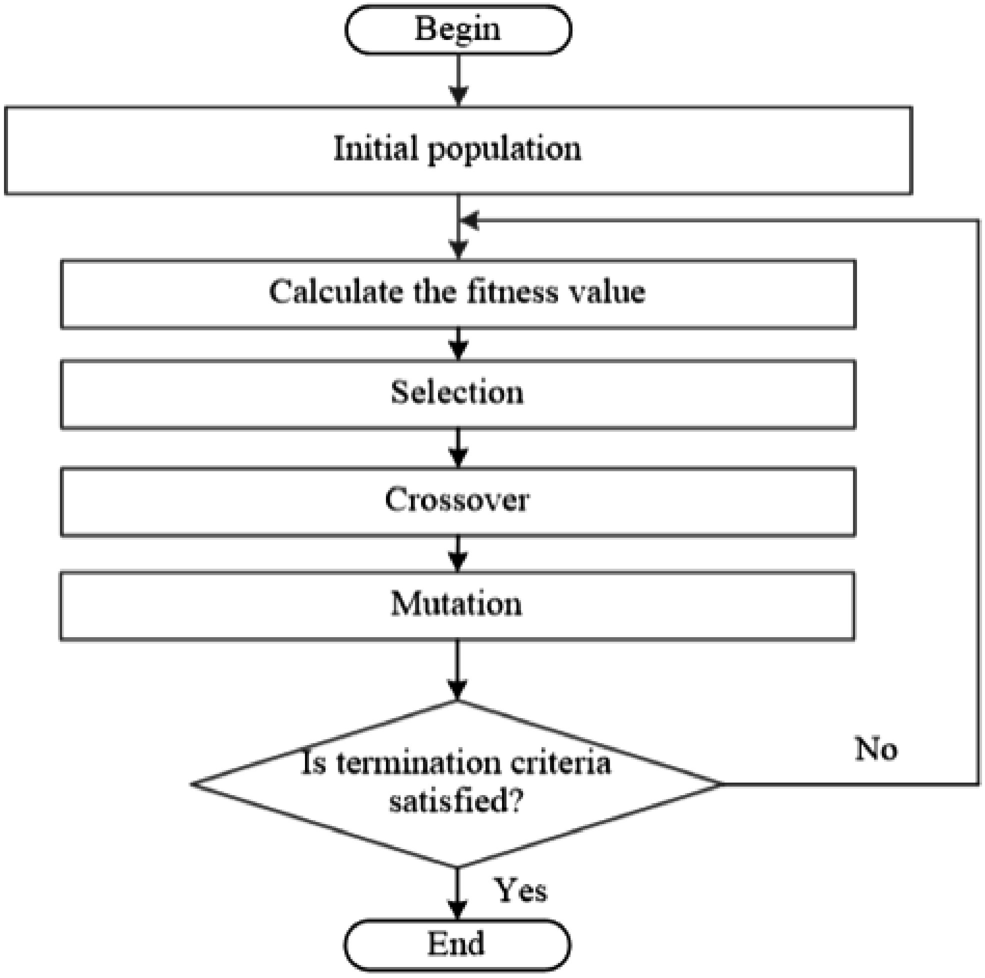

Figure 2: Flowchart of GA

3.0.1. Initialization for GA

Procedure name : Initialization
Inputs : Number of Nodes/Cities = N
Output : A set of chromosomes/solutions with cities

Algorithm1 Initialization

Step 1: begin procedure()
Step 2:
for ($i \leftarrow 1$ to population size/pop size(noc); $i \leftarrow i + 1$) do
The first phase in any genetic algorithm is to randomly create a population, or first generation, of possible solutions to the issue. Generally speaking, each individual (population member) is seen of as having a distinct set of chromosomes (phenotypes), and each one offers a potential remedy for the problem being studied. Make up a random number r between [0, N] for each chromosome. For a solution/chromosome, a distributor's tour $X_i = x_{i1}, x_{i2}, \cdots, x_{iN}$ is constructed, where $x_{i1}, x_{i2}, \cdots, x_{iN}$ expresses N cities in a tour.
end for
Step 3: end procedure

3.0.2. Roulette Wheel Selection (RWS)

Algorithm 2 states that the fitness values(here in cost of travel) of the set of chromosomes/solutions are taken into account during the RW selection process.

Procedure name : RW selection
Inputs : Probability for a chromosome = p_i, cumulative probability for a chromosome = q_i, random number = r, counter variable i = 1
Output : Updated chromosomal set based on each chromosome's fitness value

Algorithm 2 RW selection

Step 1: begin procedure
Step 2: $\sum_{i=1}^{n} f(X_i)$ //summation of the fitneses
Step 3: $p_i = \frac{f(X_i)}{\sum_{i=1}^{n} f(X_i)}$ //probability for a chromosome
Step 4: cumulative probability of X_i is $q_i = \sum_{j=0}^{i} p_i$
Step 5: for ($i \leftarrow 1$ to population_size; $i \leftarrow i+1$)
Step 6: $r \in [0,1]$;
Step 7: if $r < q_i$ then
select X_i;
Step 8: else
Go to Step -5;
Step 9: end else
Step 10: end if
Step 11: end for
Step 12: end procedure

3.0.3. Cyclic Crossover

Populations receive offspring from crossover operators. Using this method, two parents are selected at random to undergo a crossover operation in order to have new children. Algorithm 3 states that the Cyclic Crossover technique updates the probability by assessing the fitness of chromosomes.
Procedure name : Cyclic Crossover
Inputs : Cities = N, = Pr_1, Pr_2, ch_1, ch_2, crossover probability (p_c)
Output : Updated probability of chromosomes after crossover

Algorithm 3 Cyclic Crossover

Step 1: Begin procedure cycliccrossover()
Step 2: Pick two chromosomes at random, Pr_1 and Pr_2, to be your parents.
Step 3: Make the child1(ch_1) first city, C_1, at random.
Step 4: Search present city, which is chosen from Pr_1 in Pr_2, to determine the next city for child ch_1.
Find the city's location in Pr_2 and then select the city that is in the same location in Pr_1.
Step 5: Repeat this process until we have completely ch_1.
Step 6: The following step is to create a cycle using the city that was already acquired in ch_1.
Step 7: In order to obtain ch_1, duplicate the cities from Pr_2 in the spots that are currently empty.
Step 8: The parent Pr_2 is first chosen for the creation offspring ch_2, and the selection process is repeated with the procedure with Pr_1 as explained above to produce ch_1.
Step 9: End procedure cycliccrossover

3.0.4. Random Mutation

As in algorithm 4, the solution probabilities are now updated based on chromosomal fitness values via the random mutation process.

Procedure name : Random Mutation

Inputs : Mutation probability (p_m), number of cities = N, offspring's.

Output : Mutated chromosomes.

Algorithm 4 Random Mutation

Step 1: begin procedure randommutation()
Step 2: the selection method of mutation: create a random number r in between $[0,1]$ for each chromosome. When $r < p_m$, the solution/chromosome is chosen into account for the mutation operation.
Step 3: for mutation a solution, $X = x_1, x_2, \cdots, x_n$, select two numbers randomly i, j between $[1, N]$. Now, swap x_i, x_j and then update the parent chromosomes.
Step 4: $a := rand[1, N]$;
Step 5: label$-sr$: $b := rand[1, N]$;
Step 6: if $a == b$ then
Step 7: goto label$-sr$;
Step 8: for $(i \leftarrow 1; i < population\_size; i \leftarrow i+1)$
Step 9: $r := rand(0,1)$;
Step 10: if $r < p_m$ then
Step 11: choose solution $f(x_i)$ after mutation operation
Step 12: for $(j \leftarrow 1; j \leq N; j \leftarrow j+1)$
Step 13: if $x[j] == a$ then
Step 14: $x[j] := b$;
Step 15: end if
Step 16: if $x[j] == b$ then
Step 17: $x[j] := a$
Step 18: end if
Step 19: end for
Step 20: end if
Step 21: end for
Step 22: end if
Step 23: end randommutation

IV. Numerical Experiments

The proposed model comprises the following specifications and is programmatically coded in the Code::Blocks platform: Intel Core 2 Duo processor has 1.8 GHz clock speed, 1 processor, and 2 cores in total. It has 8 GB of primary memory.

4.1. Input Data

I take ten hospitals/service points/cities (N = 10, where 1 = Depot) with three (3) connecting roads and three (3) vehicles to travel in order to show the proposed approach 2DTSP.

Table - 2 lists the symmetric travel costs/expenses from a depot to the hospitals/service points and from hospitals/service points to a depot.

Table 2.1 lists the input data for the problem 2DTSP's as symmetric trip/travel time (in minutes) matrix between various hospitals/service points/cities.

The Table - 3 provide the parameters that were applied to the suggested model.

Table 2: Input Data for the problem 2DTSP's symmetric trip/travel cost matrix between various cities/hospitals/service points while using single route(R0/R1/R2) and single vehicle (V0/V1/V2), using 10 cities

		CITY - 0			CITY - 1			CITY - 2			CITY - 3			CITY - 4			CITY - 5			CITY - 6			CITY - 7			CITY - 8			CITY - 9		
		V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2
CITY - 0	R0		∞		222	212	222	122	222	220	201	222	222	222	225	222	221	201	229	229	222	222	202	221	122	200	101	222	102	222	111
	R1				222	222	222	212	202	222	101	122	210	222	100	120	222	211	222	122	221	202	211	221	221	212	221	222	221	222	212
	R2				222	229	122	222	122	222	222	222	212	212	210	215	221	121	201	222	222	222	222	220	202	102	229	222	201	122	221
CITY - 1	R0					∞		210	222	222	111	221	222	210	222	211	212	202	121	222	201	222	202	122	210	220	200	220	212	202	102
	R1							212	212	220	229	222	222	112	222	222	202	221	222	212	122	222	102	220	229	220	112	222	222	222	121
	R2							222	222	220	220	210	222	112	221	121	122	220	252	221	212	221	222	212	210	211	221	271	222	121	220
CITY - 2	R0								∞		221	222	220	221	202	221	202	102	121	121	222	212	229	221	122	222	207	212	222	202	121
	R1										212	120	212	221	222	221	201	212	200	222	210	221	212	102	222	222	222	122	222	222	70
	R2										212	221	122	229	222	212	222	221	212	209	222	229	111	222	222	220	221	202	122	221	220
CITY - 3	R0											∞		102	222	110	120	229	290	222	220	222	112	212	202	222	221	222	222	220	122
	R1													221	222	212	220	222	121	112	122	211	122	222	220	222	222	229	229	211	202
	R2													95	212	112	202	212	222	212	229	120	222	122	212	212	122	221	121	221	222
CITY - 4	R0														∞		229	212	101	221	221	221	222	212	211	221	122	202	222	220	229
	R1																222	121	102	110	122	272	229	222	220	222	222	212	212	222	221
	R2																222	221	222	202	222	222	222	121	222	102	121	200	221	222	222
CITY - 5	R0																	∞		222	122	210	222	122	222	122	229	221	122	221	122
	R1																			222	222	221	222	221	110	222	211	222	221	212	222
	R2																			222	220	112	222	122	111	212	112	221	200	229	210
CITY - 6	R0																				∞		221	212	202	229	122	200	225	210	222
	R1																						221	102	121	212	122	222	201	222	229
	R2																						222	222	221	122	202	112	122	222	222
CITY - 7	R0																							∞		222	211	212	222	101	211
	R1																									102	229	222	212	222	120
	R2																									222	122	221	212	222	122
CITY - 8	R0																										∞		222	221	222
	R1																												120	222	121
	R2																												222	292	122
CITY - 9	R0																													∞	
	R1																														
	R2																														

Table 2.1: Input Data for the problem 2DTSP's symmetric trip/travel time matrix between various hospitals/service points/cities while using single route(R0/R1/R2) and single vehicle (V0/V1/V2), using 10 cities/hospitals/service points

		CITY - 0			CITY - 1			CITY - 2			CITY - 3			CITY - 4			CITY - 5			CITY - 6			CITY - 7			CITY - 8			CITY - 9		
		V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2
CITY - 0	R0		∞		13	8	13	10	13	6	4	13	13	13	3	13	2	4	9	9	13	13	5	2	10	12	4	13	14	13	16
	R1				13	13	13	8	5	13	4	10	7	13	15	11	13	17	13	10	2	5	17	2	2	8	2	13	2	13	8
	R2				13	9	10	13	10	13	13	13	8	8	7	10	2	5	4	13	13	13	13	6	5	14	9	13	4	10	2
CITY - 1	R0					∞		7	13	13	16	2	13	7	13	17	8	5	5	13	4	13	5	10	7	6	12	6	8	5	14
	R1							8	8	6	9	13	13	18	13	13	5	2	13	8	10	13	14	6	9	6	18	13	13	13	5
	R2							13	13	6	6	7	13	18	2	5	10	6	6	2	8	2	13	8	7	17	2	3	13	5	6
CITY - 2	R0								∞		2	13	6	2	5	2	5	14	5	5	13	8	9	2	10	13	2	8	13	5	5
	R1										8	11	8	2	13	2	4	8	12	13	7	2	8	14	13	13	13	10	13	13	4
	R2										8	2	10	9	13	8	13	2	8	10	13	9	16	13	13	6	2	5	10	2	6
CITY - 3	R0											∞		14	13	2	11	9	12	13	6	13	18	8	5	13	2	13	13	6	10
	R1													2	13	8	6	13	5	18	10	17	10	13	6	13	13	9	9	17	5
	R2													4	8	18	5	8	13	8	9	11	13	10	8	8	10	2	5	2	13
CITY - 4	R0														∞		9	8	4	2	2	2	13	8	17	2	10	5	13	6	9
	R1																13	5	14	2	10	14	9	13	6	13	13	8	8	13	2
	R2																13	2	13	5	13	13	13	5	13	14	5	12	2	13	13
CITY - 5	R0																	∞		13	10	7	13	10	13	10	9	2	10	2	10
	R1																			13	13	2	13	2	2	13	17	13	2	8	13
	R2																			13	6	18	13	10	16	8	18	2	12	9	7
CITY - 6	R0																				∞		2	8	5	9	10	12	3	7	13
	R1																						2	14	5	8	10	13	4	13	9
	R2																						13	13	2	10	5	18	10	13	13
CITY - 7	R0																							∞		13	17	8	13	4	17
	R1																									14	9	13	8	13	11
	R2																									13	10	2	8	13	10
CITY - 8	R0																										∞		13	2	13
	R1																												11	13	5
	R2																												13	8	10
CITY - 9	R0																													∞	
	R1																														
	R2																														

Table 3: For the proposed model, the following parameters were used.

Parameters	Values	Unit of measure	Description
N	10	-	Number of cities/hospitals/service points
NOC/pop_size	20, 50	-	Number of chromosomes

Parameters	Values	Unit of measure	Description
Maxgen	250	-	Number of generations for the algorithm GA
p_c	0.45	-	Probability of crossover
p_m	0.20	-	Probability of mutation
T	-	Minute	Travel time
TC	-	INR	Travel cost
Z_{TC}	-	INR	Minimum travel cost
T_{max}	-	Minute	Maximum travel time constraint

4.2. Experimental Results

4.2.1. For model A

i) When Route(R)=0 and Vehicle(V)=0 selecting from Table-2.

Table 4: Output Data for the problem 2DTSP's with minimum travel cost between various cities while using single route(R0) and single vehicle (V0), using 10 cities

NOC = 20			
Iteration number	Maxgen	TC	City (Route) (Vehicle)
4	50	1579.00	(6(1)(1))-(4(1)(1))-(5(0)(0))-(8(1)(1))-(1(1)(1))-(2(1)(1))-(9(1)(1))-(0(1)(1))-(3(1)(1))-(7(1)(1))-(6)
11	70	1464.00	(2(1)(1))-(3(1)(1))-(6(1)(1))-(7(1)(1))-(0(1)(1))-(4(1)(1))-(5(0)(0))-(9(1)(1))-(1(1)(1))-(8(1)(1))-(2)
7	100	1646.00	(8(1)(1))-(1(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(9(1)(1))-(7(1)(1))-(6(0)(0))-(2(1)(1))-(5(1)(1))-(8)
8	150	1603.00	(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(0)(0))-(2(1)(1))-(3(1)(1))-(0(1)(1))-(1(1)(1))-(8(1)(1))-(7(1)(1))-(9)
9	200	1556.00	(5(0)(0))-(9(1)(1))-(0(1)(1))-(4(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(3(1)(1))-(2(1)(1))-(5)
NOC = 50			
12	100	1545.00	(0(1)(1))-(4(1)(1))-(5(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(6(1)(1))-(9(1)(1))-(8(1)(1))-(1(1)(1))-(0)
23	150	1433.00	(5(0)(0))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(6(1)(1))-(4(1)(1))-(0(1)(1))-(8(1)(1))-(1(1)(1))-(9(1)(1))-(5)
19	200	1444.00	(6(0)(0))-(2(1)(1))-(7(1)(1))-(9(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(8(1)(1))-(1(1)(1))-(6)
17	250	1447.00	(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(1(1)(1))-(8(0)(0))-(9(0)(0))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(3)

ii) When Route(R)=1 and Vehicle(V)=1 selecting from Table-2.

Table 5: Output Data for the problem 2DTSP's with minimum travel cost between various cities while using single route(R1) and single vehicle (V1), using 10 cities

NOC = 20			
Iteration number	Maxgen	TC	City (Route) (Vehicle)
18	50	1455	(9(1)(1))-(5(1)(1))-(4(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(8(1)(1))-(1(1)(1))-(6(1)(1))-(7(1)(1))-(9)
14	70	1476	(1(1)(1))-(8(1)(1))-(6(1)(1))-(4(1)(1))-(5(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(9(1)(1))-(1)
13	100	1464	(8(1)(1))-(9(1)(1))-(2(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(7(1)(1))-(6(1)(1))-(1(1)(1))-(8)
12	150	1476	(1(1)(1))-(8(1)(1))-(6(1)(1))-(4(1)(1))-(5(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(9(1)(1))-(1)
7	200	1545	(8(1)(1))-(1(1)(1))-(4(1)(1))-(0(1)(1))-(5(1)(1))-(9(1)(1))-(7(1)(1))-(2(1)(1))-(3(1)(1))-(6(1)(1))-(8)
NOC = 50			
30	100	1436	(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(8(1)(1))-(1(1)(1))-(9(1)(1))-(2(1)(1))-(7(1)(1))-(6(1)(1))-(3)
23	150	1528	(9(1)(1))-(5(1)(1))-(4(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(0(1)(1))-(3(1)(1))-(9)
26	200	1526	(6(1)(1))-(3(1)(1))-(9(1)(1))-(8(1)(1))-(1(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(2(1)(1))-(7(1)(1))-(6)
20	250	1547	(3(1)(1))-(9(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(4(1)(1))-(5(1)(1))-(0(1)(1))-(3)

iii) When Route(R)=2 and Vehicle(V)=2 selecting from Table-2.

Table 6: Output Data for the problem 2DTSP's with minimum travel cost between various cities while using single route(R2) and single vehicle (V2), using 10 cities

NOC = 20			
Iteration number	Maxgen	TC	City (Route) (Vehicle)
19	50	1575	(7(2)(2))-(6(1)(1))-(1(1)(1))-(8(1)(1))-(5(1)(1))-(4(1)(1))-(9(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7)
5	70	1669	(2(1)(1))-(0(2)(2))-(1(1)(1))-(8(1)(1))-(9(1)(1))-(6(1)(1))-(3(1)(1))-(5(1)(1))-(4(1)(1))-(7(1)(1))-(2)
12	100	1588	(2(1)(1))-(9(1)(1))-(6(1)(1))-(8(1)(1))-(1(2)(2))-(0(1)(1))-(3(1)(1))-(4(1)(1))-(5(1)(1))-(7(1)(1))-(2)
14	150	1566	(8(1)(1))-(5(2)(2))-(7(2)(2))-(9(1)(1))-(0(1)(1))-(2(1)(1))-(3(1)(1))-(4(1)(1))-(6(1)(1))-(1(1)(1))-(8)
8	200	1643	(3(1)(1))-(9(1)(1))-(1(1)(1))-(8(1)(1))-(2(1)(1))-(6(1)(1))-(7(1)(1))-(5(1)(1))-(4(1)(1))-(0(1)(1))-(3)
NOC = 50			

NOC = 20			
24	100	1474	(7(1)(1))-(2(1)(1))-(3(1)(1))-(0(2)(2))-(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(7)
20	150	1573	(6(2)(2))-(8(1)(1))-(7(1)(1))-(2(2)(2))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(1(1)(1))-(9(1)(1))-(6)
27	200	1455	(5(2)(2))-(6(1)(1))-(1(1)(1))-(8(1)(1))-(9(1)(1))-(4(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(5)
21	250	1555	(5(1)(1))-(9(1)(1))-(0(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(5)

Table 7: Model A - 2DTSP with minimum travel cost.

Model	NOC	Maxgen	City (Route) (Vehicle)	TC (INR)
A	50	150	(5(1)(1)) - (3(1)(1)) - (2(1)(1)) - (7(1)(1)) - (6(1)(1)) - (4(1)(1)) - (0(1)(1)) - (8(1)(1)) - (1(1)(1)) - (9(1)(1)) -(5)	1433

4.2.2. For model B

i) When Route(R)=0 and Vehicle(V)=0 selecting from Table-2 and Table 2.1.

Table 8: Output Data for the problem 2DTSP's with minimum travel cost and travel time between various cities while using single route(R0) and single vehicle (V0), using 10 cities

NOC = 20				
Iteration number	Maxgen	TC	Travel time	City (Route) (Vehicle)
4	50	1579.00	10+5+10+18+8+13+13+10+13+14=114	(6(1)(1))-(4(1)(1))-(5(0)(0))-(8(1)(1))-(1(1)(1))-(2(1)(1))-(9(1)(1))-(0(1)(1))-(3(1)(1))-(7(1)(1))-(6)
11	70	1464.00	11+10+14+2+15+5+8+13+18+13=109	(2(1)(1))-(3(1)(1))-(6(1)(1))-(7(1)(1))-(0(1)(1))-(4(1)(1))-(5(0)(0))-(9(1)(1))-(1(1)(1))-(8(1)(1))-(2)
7	100	1646.00	18+13+10+15+13+13+14+5+8+17=126	(8(1)(1))-(1(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(9(1)(1))-(7(1)(1))-(6(0)(0))-(2(1)(1))-(5(1)(1))-(8)
8	150	1603.00	8+5+10+5+11+10+13+18+9+13=102	(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(0)(0))-(2(1)(1))-(3(1)(1))-(0(1)(1))-(1(1)(1))-(8(1)(1))-(7(1)(1))-(9)
9	200	1556.00	10+13+15+13+18+10+14+13+11+8=125	(5(0)(0))-(9(1)(1))-(0(1)(1))-(4(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(3(1)(1))-(2(1)(1))-(5)
NOC = 50				
12	100	1545.00	15+5+13+11+14+14+13+13+18+13=129	(0(1)(1))-(4(1)(1))-(5(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(6(1)(1))-(9(1)(1))-(8(1)(1))-(1(1)(1))-(0)
23	150	1433.00	11+11+14+14+10+15+2+18+13+8=116	(5(0)(0))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(6(1)(1))-(4(1)(1))-(0(1)(1))-(8(1)(1))-(1(1)(1))-(9(1)(1))-(5)
19	200	1444.00	5+14+13+17+10+15+5+17+18+10=124	(6(0)(0))-(2(1)(1))-(7(1)(1))-(9(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(8(1)(1))-(1(1)(1))-(6)

NOC = 20				
17	250	1447.00	10+15+5+2+18+13+3+14+14+11=105	(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(1(1)(1))-(8(0)(0))-(9(0)(0))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(3)

ii)

ii) When Route(R)=1 and Vehicle(V)=1 selecting from Table-2 and Table 2.1.

Table 9: Output Data for the problem 2DTSP's with minimum travel cost and travel time between various cities while using single route(R1) and single vehicle (V1), using 10 cities

NOC = 20				
Iteration number	Maxgen	TC	Travel time	City (Route) (Vehicle)
18	50	1455	8+5+15+10+11+13+18+10+14+13=117	(9(1)(1))-(5(1)(1))-(4(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(8(1)(1))-(1(1)(1))-(6(1)(1))-(7(1)(1))-(9)
14	70	1476	18+10+10+5+17+10+11+14+13+13=121	(1(1)(1))-(8(1)(1))-(6(1)(1))-(4(1)(1))-(5(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(9(1)(1))-(1)
13	100	1464	13+13+11+10+15+5+2+14+10+18=111	(8(1)(1))-(9(1)(1))-(2(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(7(1)(1))-(6(1)(1))-(1(1)(1))-(8)
12	150	1476	18+10+10+5+17+10+11+14+13+13=121	(1(1)(1))-(8(1)(1))-(6(1)(1))-(4(1)(1))-(5(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(9(1)(1))-(1)
7	200	1545	18+13+15+17+8+13+14+11+10+10=129	(8(1)(1))-(1(1)(1))-(4(1)(1))-(0(1)(1))-(5(1)(1))-(9(1)(1))-(7(1)(1))-(2(1)(1))-(3(1)(1))-(6(1)(1))-(8)
NOC = 50				
30	100	1436	10+15+5+17+18+13+13+14+14+10=129	(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(8(1)(1))-(1(1)(1))-(9(1)(1))-(2(1)(1))-(7(1)(1))-(6(1)(1))-(3)
23	150	1528	8+5+13+18+10+14+14+5+10+17=114	(9(1)(1))-(5(1)(1))-(4(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(0(1)(1))-(3(1)(1))-(9)
26	200	1526	10+17+13+18+13+15+5+8+14+14=127	(6(1)(1))-(3(1)(1))-(9(1)(1))-(8(1)(1))-(1(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(2(1)(1))-(7(1)(1))-(6)
20	250	1547	17+13+18+10+14+14+13+5+17+10=131	(3(1)(1))-(9(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(4(1)(1))-(5(1)(1))-(0(1)(1))-(3)

iii) When Route(R)=2 and Vehicle(V)=2 selecting from Table-2 and Table 2.1.

Table 10: Output Data for the problem 2DTSP's with minimum travel cost and travel time between various cities while using single route(R2) and single vehicle (V2), using 10 cities

NOC = 20				
Iteration number	Maxgen	TC	Travel time	City (Route) (Vehicle)
19	50	1575	2+10+18+17+5+13+13+10+11+14=113	(7(2)(2))-(6(1)(1))-(1(1)(1))-(8(1)(1))-(5(1)(1))-(4(1)(1))-(9(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7)
5	70	1669	5+10+18+13+13+10+13	(2(1)(1))-(0(2)(2))-(1(1)(1))-(8(1)(1))-(9(1)(1))-(6(1)(1))-

NOC = 20				
			+5+13+14=114	(3(1)(1))-(5(1)(1))-(4(1)(1))-(7(1)(1))-(2)
12	100	1588	13+13+10+18+10+10+13+5+2+14=108	(2(1)(1))-(9(1)(1))-(6(1)(1))-(8(1)(1))-(1(2)(2))-(0(1)(1))-(3(1)(1))-(4(1)(1))-(5(1)(1))-(7(1)(1))-(2)
14	150	1566	17+16+10+13+5+11+13+10+10+18=123	(8(1)(1))-(5(2)(2))-(7(2)(2))-(9(1)(1))-(0(1)(1))-(2(1)(1))-(3(1)(1))-(4(1)(1))-(6(1)(1))-(1(1)(1))-(8)
8	200	1643	17+13+18+13+7+14+2+5+15+10=114	(3(1)(1))-(9(1)(1))-(1(1)(1))-(8(1)(1))-(2(1)(1))-(6(1)(1))-(7(1)(1))-(5(1)(1))-(4(1)(1))-(0(1)(1))-(3)
NOC = 50				
24	100	1474	14+11+10+2+8+5+10+10+18+6=94	(7(1)(1))-(2(1)(1))-(3(1)(1))-(0(2)(2))-(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(7)
20	150	1573	18+9+14+10+10+15+5+2+13+13=109	(6(2)(2))-(8(1)(1))-(7(1)(1))-(2(2)(2))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(1(1)(1))-(9(1)(1))-(6)
27	200	1455	18+10+18+13+13+15+10+11+14+2=124	(5(2)(2))-(6(1)(1))-(1(1)(1))-(8(1)(1))-(9(1)(1))-(4(1)(1))-(0(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(5)
21	250	1555	8+13+15+10+10+18+13+11+14+2=114	(5(1)(1))-(9(1)(1))-(0(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(3(1)(1))-(2(1)(1))-(7(1)(1))-(5)

Table 11: Model B - 2DTSP with minimum travel cost with travel time.

Model	NOC	Maxgen	City (Route) (Vehicle)	TC (INR)	Travel time
A	50	150	(5(1)(1)) - (3(1)(1)) - (2(1)(1)) - (7(1)(1)) - (6(1)(1)) - (4(1)(1)) - (0(1)(1)) - (8(1)(1)) - (1(1)(1)) - (9(1)(1)) -(5)	1433	116 minutes

4.2.2. For model C

i) When Route(R)=0 and Vehicle(V)=0 selecting from Table-2 and Table 2.1.

Table 12: Output Data for the problem 2DTSP's with minimum travel cost under travel time constraint between various cities while using single route(R0) and single vehicle (V0), using 10 cities

NOC = 20				
Iteration number	Maxgen	TC	Travel time constraint under 103 minutes	City (Route) (Vehicle)
8	150	1603.00	8+5+10+5+11+10+13+18+9+13 =102	(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(0)(0))-(2(1)(1))-(3(1)(1))-(0(1)(1))-(1(1)(1))-(8(1)(1))-(7(1)(1))-(9)
NOC = 50				
Iteration number	Maxgen	TC	Travel time constraint under 106 minutes	City (Route) (Vehicle)
17	250	1447.00	10+15+5+2+18+13+3+14+14+11 =105	(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(1(1)(1))-(8(0)(0))-(9(0)(0))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(3)

ii) When Route(R)=1 and Vehicle(V)=1 selecting from Table-2 and Table 2.1.

Table 13: Output Data for the problem 2DTSP's with minimum travel cost under travel time constraint between various cities while using single route(R1) and single vehicle (V1), using 10 cities

NOC = 20				
Iteration number	Maxgen	TC	Travel time constraint under 113 minutes	City (Route) (Vehicle)
13	100	1464	13+13+11+10+15+5+2+14+10+18=111	(8(1)(1))-(9(1)(1))-(2(1)(1))-(3(1)(1))-(0(1)(1))-(4(1)(1))-(5(1)(1))-(7(1)(1))-(6(1)(1))-(1(1)(1))-(8)
NOC = 50				
Iteration number	Maxgen	TC	Travel time constraint under 115 minutes	City (Route) (Vehicle)
23	150	1528	8+5+13+18+10+14+14+5+10+17=114	(9(1)(1))-(5(1)(1))-(4(1)(1))-(1(1)(1))-(8(1)(1))-(6(1)(1))-(7(1)(1))-(2(1)(1))-(0(1)(1))-(3(1)(1))-(9)

iii) When Route(R)=2 and Vehicle(V)=2 selecting from Table-2 and Table 2.1.

Table 14: Output Data for the problem 2DTSP's with minimum travel cost under travel time constraint between various cities while using single route(R2) and single vehicle (V2), using 10 cities

NOC = 20				
Iteration number	Maxgen	TC	Travel time constraint under 109 minutes	City (Route) (Vehicle)
12	100	1588	13+13+10+18+10+10+13+5+2+14=108	(2(1)(1))-(9(1)(1))-(6(1)(1))-(8(1)(1))-(1(2)(2))-(0(1)(1))-(3(1)(1))-(4(1)(1))-(5(1)(1))-(7(1)(1))-(2)
NOC = 50				
Iteration number	Maxgen	TC	Travel time constraint under 95 minutes	City (Route) (Vehicle)
24	100	1474	14+11+10+2+8+5+10+10+18+6=94	(7(1)(1))-(2(1)(1))-(3(1)(1))-(0(2)(2))-(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(7)

Table 15: Model C - 2DTSP with minimum travel cost under travel time constraint.

Model	**NOC**	**Maxgen**	**Iteration number**	**City (Route) (Vehicle)**	**TC (INR)**	**Tour time constraint (96 minutes)**
C	50	100	24	(7(1)(1))-(2(1)(1))-(3(1)(1))-(0(2)(2))-(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(7)	1474	94

V. Discussion

It is observed in Model - A (Table 4 to 6) that when NOC=50, iteration number=23 and maxgen=150 at Table-4, the algorithm get more best minimum travel cost(TC)= INR 1433.00. The optimal results are shown for Model A at Table-7 with TC INR 1433.00 and optimal path is (5(1)(1)) - (3(1)(1)) - (2(1)(1)) - (7(1)(1)) - (6(1)(1)) - (4(1)(1)) - (0(1)(1)) - (8(1)(1)) - (1(1)(1)) - (9(1)(1)) -(5).

Observations show on Table 8 to 10 for Model B that when I am considering minimum travel time (here 94 minutes) then we got at Table 10, TC = INR 1474.00 with optimal path (7(1)(1))-(2(1)(1))-(3(1)(1))-(0(2)(2))-(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(7). Now, when NOC=50, iteration number=23 and maxgen=150 at Table-8, the algorithm get best minimum travel cost(TC)= INR 1433.00 with travel time 116 minutes and the optimal path is (5(1)(1)) - (3(1)(1)) - (2(1)(1)) - (7(1)(1)) - (6(1)(1)) - (4(1)(1)) - (0(1)(1)) - (8(1)(1)) - (1(1)(1)) - (9(1)(1)) -(5). Table 11 shows the above mentioned results.

As a result from Table 12 to 14, in my final (more realistic) model under tour time constraint 96 minutes, it has been observed that NOC=50, iteration number=24 and maxgen=100 at Table-14, the algorithm get best minimum travel cost(TC)= INR 1474.00 with optimal tour (7(1)(1))-(2(1)(1))-(3(1)(1))-(0(2)(2))-(9(1)(1))-(5(1)(1))-(4(1)(1))-(6(1)(1))-(8(1)(1))-(1(1)(1))-(7). The above decisions also showed in Table 15.

But, when NOC=50, iteration number=17 and maxgen=250 at Table-12, the algorithm get more best minimum travel cost(TC)= INR 1447.00 than before but here travel time is required 105 minutes.

Finally, Table 15 shows the best optimum results with minimum travel cost and under tour time constraint.

VI. Conclusions

As per the investigator's best knowledge, this model is the first model solved by a Genetic Algorithm for medical equipment distribution to different service points. Hence we can enhance the model under a fuzzy tour time and carbon emission constraint and develop the algorithms. The travel cost and time data may be crisped in nature and for an imprecise environment like fuzzy.

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