OPTIMAL ROUTE PLANNING OF TOURISM SPOTS IN TRIPURA, INDIA USING MULTI-TRIP VEHICLE ROUTING PROBLEM

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Abstract
Optimal travel route selection in real time basis minimizes the transportation cost for the tourists and guarantees the ease of travel as well. Accordingly, this paper deals with the problem of selecting the appropriate route selection to visit the identified tourists' spots in Tripura, India using the vehicle routing problem with time windows. The different tourist spots in the study area are identified from the Tourism Department of the Government of Tripura. This study considers only two cities as the gateway to reach to Tripura. After which, based on Bing map portal, geographic information for all the selected tourist spots is mapped; and one to one distance matrix is prepared considering the identified tourist spots and the two-gateway point of Tripura. The result so derived is compared and contrasted with the traditional route followed by the travel operators of Tripura; and found significant differences in terms of cost of transportation and time spent to visit the different tourist spots in Tripura. Finally, this paper concluded that selection of optimal route for transport network of tourism spots in Tripura, India using multi-trip vehicle routing problem can ensure the ease of travel and satisfaction for the tourists visiting in Tripura, India.

Key words: *India, Multi-trip, Tourist Routes, Tripura, Vehicle Routing Problem.*

JEL Classification: R42, *Z32, Z38*

I.INTRODUCTION

Selection of appropriate route for sight visit is one of the pre-conditions for ensuring the ease of travel and satisfaction for the tourists. Optimal travel route selection in real time basis minimizes the transportation cost for the tourists and guarantees the ease of travel as well. Hence, it is an economic imperative to study the issue of selecting the optimal route for travel using the multi-trip vehicle routing problem (VRP) with time windows. Accordingly, this paper deals with the problem of selecting the appropriate route selection to visit the identified tourists' spots in Tripura, India using the vehicle routing problem with time windows. For this, the different tourist spots in the study area are identified from the Tourism Department of the Government of Tripura. This study considers only two cities as the gateway to reach to Tripura. Majority of the tourist's visit Tripura through Agartala Airport where as Dharmanagar, located near the Assam border in the extreme north of Tripura is the gateway for the tourists travelling through Train or Bus. Accordingly, the objective of this paper is to find the optimal transport network of tourism spots in Tripura, India which can minimize the transport cost associated with the trip.

The remaining paper is organized as follows: Section 2 presents the brief review of literature to identify the gap in the existing literature; and on the basis of which the objective of this paper is identified. Section 3 introduces the materials and methods used in this study; and the results are presented ad discussed in Section 4. Finally, this paper concluded in Section 5.

II.REVIEW OF LITERATURE

There has been a substantial study on Vehicle Routing Problem (VRP) which was first introduced by Dantzig and Ramser (Dantzig and Ramser, 1959). Several researchers have applied this technique to solve optimization problems in different fields. Laporte, et al. (1984, 1988, and 2009) described lucidly as a problem to determine the shortest route or circuit in a graph with 'n' number of nodes provided each node is visited exactly once. Given an origin terminal and a number of different geographical destinations, the VRP aid to find a set of routes that would enable to visit all destinations with a least total distance covered (Brandao and Mercer 1998). Out of different models of VRP in the existing literature, Vehicle Routing Problem with Time Windows (VRPTW) has been employed in which each destination is associated with a time frame called time window in touring such destinations (Toth and Vigo 2002). Baker and Ayechew (2003) used genetic algorithm in solving VRP particularly those associated with time windows which however did not make satisfactory impact. Flognfeldt (2005) studied and analysed theoretically the patterns of tourist routes which would fall under VRP had that be formulated mathematically as the importance of transport and time spent on destinations were asserted in tourism planning. Leong and Liu (2006) also attempted to minimize the number of routes and total distance covered in a VRPTW using a multi-agent approach. Although such approach is in a developing stage, but yields a good result which are comparable with those in existing literatures. Jing Fan (2011) made a study on VRP with simultaneous pickup and delivery where customers' satisfaction is considered based on time windows. It was observed that improvement in computational results was done using a tabu-search algorithm. Rodriguez, et al. (2012) studied and proposed a mathematical design so that a tourist can opt for best suited itinerary subject to certain given constraints. Similarly, the works of Han, Guan and Duan (2014) attempted to maximize tourists' satisfaction while minimizing tour distance using multi-objective optimization technique. Liu, et al. (2014) studied how traffic jams and queuing time affects the total visiting time for self-driving tourists. It was proposed that adopting routes based on interests and preferences would be efficient for self-driving tourists. Also using real time traffic information with vehicle-to-vehicle communication system can reduce waiting time. Another relevant study regarding tourist trip design problems was done by Gavalas, et al. (2014) where attempt has been made to maximize tourist satisfaction while considering number of constraints like distance of tourist spots, time spent, entrance fees and others alike using different techniques of orienteering problem. Ji et al. (2015) used VRP model and genetic algorithm to analyze the total cost structure of cold chain logistics in which it is found that the model and the algorithm used provides a feasible and effective optimization. Wu et al. (2017) tried to optimize a tour route planning with an objective to maximize tourism experience subject to time and cost constraints. Similar to VRP, a tour route planning problem technique of optimization was used and its feasibility was validated citing an example of tourism transportation network. Further, on conducting a sensitivity analysis on parameters of tourism experience, it was found that tourists' attraction, travelling time and travelling cost had significant influence on tourism route planning. Uwaisy et al. (2019) made a recommendation on scheduling tourism routes based on the Travelling Salesman Problem (TSP). A tabu search method combined with Multi-Attribute Utility Theory (MAUT) was used in order to find optimal route based on number of tourist spots, costs and popularity. The tabu search was found more effective when compared to firefly method. Very recently, Meza and Torres (2021) made a study on tourist trip design along with transport mode selection and climate considerations. The reason behind transport mode selection was the effects of COVID-19 on the travelling patterns of tourists. An attempt was made for a sustainable tourism by introducing CO2 emissions as one of tourism constraints. Firstly, an optimization model was used to determine tour routes and mode of transport considering heterogeneous preferences of tourists. Later, the level of CO2 emissions for such routes and mode of transport is studied. It was found that individual tourists are more climate conscious than group tourists. Simultaneously, tourists prefer to tour in groups rather than individually. Other worth mentioning constructive optimization techniques used by researchers to determine optimal tour routes include Minimum Spanning Tree (Fisher 1994; Kumar, et al. 2014) and Ant Colony Optimization (Huang 2013; Zhang 2019; Qian and Zhong 2019).

The literatures mentioned above all employed optimization techniques to find optimal tour routes by considering mostly time and costs constraints. This study shall use VRP technique in finding the optimal tour routes of selected tourist spots. Although VRP is also an optimization technique; its application in tourism route planning is sparsely seen in the existing literature. As such, the multi-trip Vehicle Routing Problem with Time Windows (VRPTW) can be applied to find optimal routes of different tourist spots so as to maximize the number of spots visited while minimizing the total distance covered and thereby minimizing the cost of travelling. From the above-mentioned brief review of literature, it transpires that there is a dearth of studies on the application of VRP in the context of selection of multi-trip tourism route determination, in general; and in the context of India, in particular. Hope, this study shall attempt to fill that caveat in the existing literature.

III.MATERIALS & METHODS

This study applied two stage solution procedures in finding out an optimal solution: Dijikstr Algorithm is applied in the first stage to find out the shortest distance matrix, and then the solution is used in the VRP to calculate the expected costs in the second stage (Hadjiconstantinou & Roberts, 2002). The specific objective of applying this method is to minimize the cost and duration of transportation by identifying optimal tourist routes from depot to destinations. To determine the optimal route for tourist, this study applied the VRP Spreadsheet Solver developed by Erdogan (2017). This open source VRP Spreadsheet Solver consists of different elements of a VRP in separate worksheets: VRP solver console, Locations, Distances, Vehicles, Solution and Visualization.

Let G = (V, E) be a complete and undirected graph where V = {0, ⋯, n} is the vertex set and E is the edge set. Vertex set Vc = {1, ⋯, n} corresponds to n customers, whereas vertex 0 corresponds to the depot.

The specific objective of applying this method is to minimize the cost and duration of transportation by identifying optimal distribution route of tourists from depot to consumers. Algebraically, the problem can be written as:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_{ij}$$

$$\textit{subject to } \sum_{j=1}^{n} x_{ij} = 1 \ \forall i=2,..........,n$$

$$\sum_{j=1}^{n} x_{ji} = 1 \ \forall i=2,..........,n$$

$$\sum_{j=1}^{n} f_{ji} - \sum_{j=1}^{n} f_{ij} = D_i \ \forall i=2,..........,n$$

$$0 \le f_{ij} \le C x_{ij} \ \forall i,j=2,..........,n$$

$$x_{ij} \in [0,1]$$

The objective of VRP is to minimize the total distance travelled within the network. The constraints are many fold.

Where,

n : number of nodes;

d_{ij} : distance from node i to node j;

D_i : demand at node i;

C: Capacity of each vehicle.

Moreover,

$x_{ij} = 1$; if a vehicle goes from node i to node j (binary);

f_{ij} : number of units transported from node i to node j.

First constraint guarantees that the shortest path will be chosen between any two nodes; whereas the second constraint is simply maintain the symmetry condition. The third condition is related to the requirement at each of the destination; and the fourth constraint is the capacity constraint of the vehicles. Finally, the binary nature of the decision variable is presented.

For determining the location map of the tourist spot, the API keys from Bing map portal is used; and this open-source version of user-friendly interface is extensively utilized in minimizing the distance travel from the two different starting nodes (Agartala and Dharmanagar) to different tourist spots.

The distance between two depos (Agartala and Dharmanagar) can be covered by railway; and the scenic beauty enjoyed by the travelers during train journey is another attraction. Hence, this study separately runs the VRP for these two depos; and finally construct the Optimal Tourist Route Network based on VRP Spreadsheet Solver developed by Erdogan (2017).

IV. RESULTS & DISCUSSIONS

This study has chosen the road network of the state of Tripura, India. Sen et al. (2012) described this State as a pseudo landlocked region since it is geographically not landlocked as it is connected with Kolkata port within India; but the aerial distance from Kolkata from the state capital of Tripura is just the one fourth of its road distance from its nearest port within India. For this study, we have chosen different tourist spots of the state of Tripura, India and construct a network based on those spots. Presently, Tripura is administratively divided into eight districts and several subdivisions within each district. There are several tourist spots as identified by the Department of Tourism, Government of Tripura. However, only major spots have been considered for the purpose of this study. Including two depots and a total destination of twenty, each of these have been assigned with nodes as shown in Table 1.

Table 1: Location details of the different Tourist Spots & Two Depots in Tripura

Nodes	Description	Address	District	Latitude	Longitude
N0	Depot A	Tripura State Guest House, Agartala	West Tripura	23.83	91.28
N1	Depot B	Juri Tourist LodgeDharmanagar	North Tripura	24.38	92.16
N2	Destination 1	Rowa Wildlife Sanctuary, Rowa	North Tripura	24.37	92.17
N3	Destination 2	Eden Tourist Lodge, Jampui Hill, Vanghmun	North Tripura	23.94	92.28
N4	Destination 3	Unakoti Archaeological Site, Kailashahar	Unakoti	24.24	92.02
N5	Destination 4	Dumboor Lake	Dhalai	23.83	91.92
N6	Destination 5	Sanaiya Waterfalls	Khowai	23.83	91.92
N7	Destination 6	Baramura Eco Park, Teliamura	West Tripura	23.90	91.64
N8	Destination 7	ChaturdashDevta Temple, Khayerpur	West Tripura	23.82	91.29
N9	Destination 8	Khumulwang Eco Park, Kumulwng,	West Tripura	23.82	91.29
N10	Destination 9	Neermahal Water Palace, Melaghar	Sepahijala	23.49	91.33
N11	Destination 10	Kasba Kali Temple, Kamalasagar	Sepahijala	23.74	91.18
N12	Destination 11	Buddhist Stupa, Baxanagar	Sepahijala	23.62	91.17
N13	Destination 12	Sepahijala Wildlife Sanctuary	Sepahijala	23.67	91.32
N14	Destination 13	Gomati Wildlife Sanctuary	Gomati	23.83	91.92
N15	Destination 14	Tepania Eco Park, Udaipur	Gomati	23.53	91.50
N16	Destination 15	Chabimura	Gomati	23.53	91.50
N17	Destination 16	Tripura Sundari Temple, Matabari	Gomati	23.53	91.50
N18	Destination 17	MahamuniPegoda, Manubankul	South Tripura	23.37	91.59
N19	Destination 18	Pilak Archaeological Sites, Jolaibari	South Tripura	23.22	91.61
N20	Destination 19	Trishna Wildlife Sanctuary, Belonia	South Tripura	23.24	91.47
N21	Destination 20	Kalapania Nature Park, Sabroom	South Tripura	23.00	91.73

Out of the selected nodes, Dharmanagar (N1) is the entry point in Assam border via railway located in the extreme north of Tripura; and Agartala (N1) is the state capital of this state and connected via Flights with all over India. Out of selected tourist spots; Sepahijala district, Gomati district and South Tripura district have four tourist spots each. West Tripura and North Tripura district have three and two tourist spots, respectively whereas Khowai, Dhalai and Unakoti districts have one tourist spot each. These are presented below:

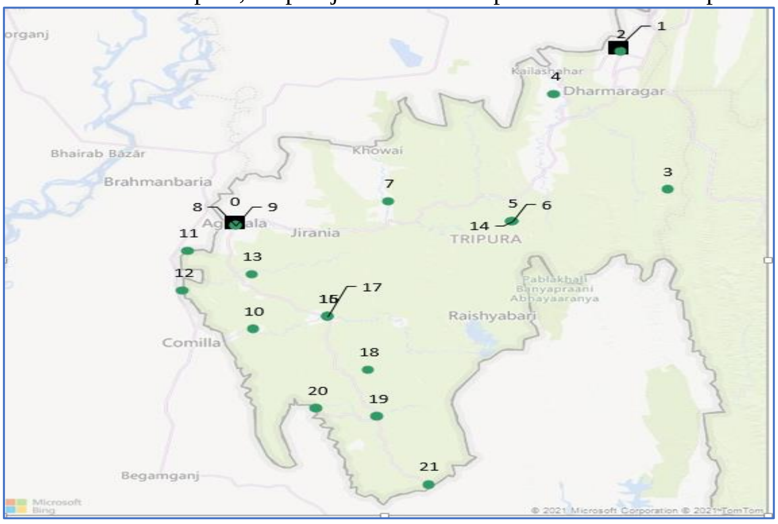

Figure 1: Location of the Selected Nodes

Table 2 represents the adjacency matrix of nodes which is prepared on the basis of existing road connectivity available in Tripura; and position of selected nodes in map (Figure 1) is created on the basis of Table 1.

Table 2: Adjacency Matrix of Selected Tourist spots in Tripura

Nodes	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
N0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
N1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N3	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N4	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
N6	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
N7	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0
N8	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
N9	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
N10	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0
N11	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
N12	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
N13	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0
N14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0
N15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
N16	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
N17	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0
N18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0
N19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
N20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
N21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0

After which the Table 3 represents the distance matrix of different nodes under study. The R package "igraph" (Csardi and Nepusz, 2006) is used to find the shortest distance matrix of different selected nodes representing the tourist spots in Tripura. These are presented in detail below:

Table 3: Shortest Distance Matrix of Selected Tourist spots in Tripura

Nodes	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
N0	0	172	171	155	143	100	100	52	2	2	49	27	37	27	100	53	53	53	85	100	91	134
N1	173	0	3	88	36	109	109	134	173	173	202	198	207	198	109	193	193	193	196	241	231	275
N2	172	2	0	86	37	108	108	133	172	172	200	196	206	196	108	192	192	192	194	239	229	273
N3	155	88	86	0	107	91	91	117	155	155	184	180	190	180	91	175	175	175	178	223	213	257
N4	142	36	37	107	0	99	99	124	163	163	191	187	197	187	99	182	182	182	185	230	220	264
N5	101	109	107	91	98	0	0	63	101	101	130	126	135	126	0	121	121	121	88	124	113	158
N6	101	109	107	91	98	0	0	63	101	101	130	126	135	126	0	121	121	121	88	124	113	158
N7	52	134	133	117	124	62	62	0	52	52	81	77	86	76	62	72	72	72	75	120	110	154
N8	2	173	172	155	163	101	101	52	0	0	48	26	36	26	101	52	52	52	84	100	90	134
N9	2	173	172	155	163	101	101	52	0	0	48	26	36	26	101	52	52	52	84	100	90	134
N10	49	201	200	184	191	129	129	81	49	49	0	44	34	29	129	24	24	24	50	65	42	100
N11	27	197	196	180	169	125	125	77	27	27	43	0	27	21	125	47	47	47	79	94	85	129
N12	36	207	206	190	178	135	135	86	36	36	34	27	0	23	135	49	49	49	81	96	70	130
N13	27	197	196	180	168	125	125	76	26	26	29	21	23	0	125	33	33	33	65	80	71	114
N14	101	109	107	91	98	0	0	63	101	101	130	126	135	126	0	121	121	121	88	124	113	158
N15	53	192	191	175	182	120	120	72	52	52	24	48	49	33	120	0	0	0	31	47	37	81
N16	53	192	191	175	182	120	120	72	52	52	24	48	49	33	120	0	0	0	31	47	37	81
N17	53	192	191	175	182	120	120	72	52	52	24	48	49	33	120	0	0	0	31	47	37	81
N18	85	195	194	178	185	88	88	75	84	84	50	79	81	65	88	31	31	31	0	24	25	58
N19	100	240	239	223	230	125	125	119	100	100	65	95	96	80	125	47	47	47	24	0	21	35
N20	91	230	229	213	220	113	113	110	90	90	42	85	70	71	113	37	37	37	25	21	0	55
N21	134	274	273	257	264	159	159	153	134	134	100	129	130	114	159	81	81	81	58	35	55	0

Presently, the different Tours and Travel Companies in Tripura are charging a fixed cost of INR 1000 and a variable cost of INR 10 per km of distance travel for hired car including the charges of driver. Further, for night stay with hired car, an additional INR 1000 is charged from the tourist party for daily allowance and stay of the driver. Considering their daily allowances as a part of fixed cost, total cost is accordingly calculated. Details of expenditure is calculated on the basis of tour packages offered by the most of the Tours and Travels companies in Tripura.

Table 4: Details of Expenditure incurred for hired cars at present

Sl No	Route	Day	Distance (km)	Cost (INR)
1	Agartala >>Kasba kali mandir->>Sipahijala>>Baxanagar>>Neermahal>> Tripura Sundari>> Agartala	Day 1	193	2930
2	Agartala >>Chhabimura>>Dumboor Lake >> Agartala	Day 2	268	3680
3	Agartala >>Baramura>>Sanaiya Waterfalls>>Agartala (including local sight-seeing)	Day 3	161	2610
4	Agartala >>Dharmanagar>>Unakoti>>Rowa Forests >>Dharmanagr [Night stay]	Day 4	221	4210
5	Dharmanagar >> Eden Tourist Lodge [Night stay]	Day 5	110	3100
6	Eden Tourist Lodge >> Agartala	Day 6	189	2890
Total		*6 days*	*1142 km*	*INR19420*

Finally, the result provides us the visualization of the optimal set of routes as shown in figure 2. Three such routes are identified, which are marked by the different colors. Moreover, two depots may be travelled by railway since the scenic beauty during travel by railway is one of the major tourist attractions.

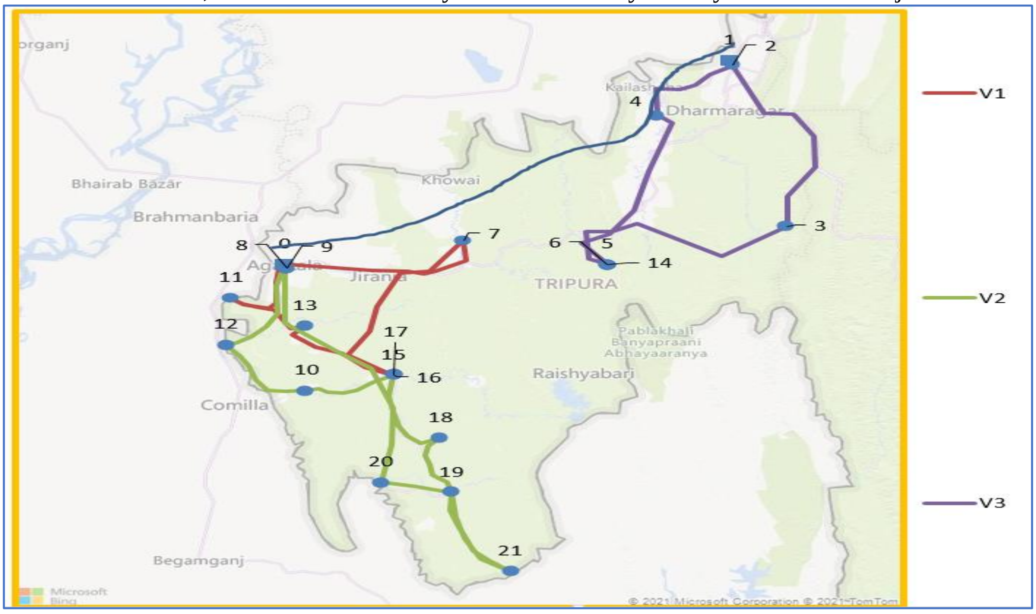

Figure 2: Optimal VRP Solution

In the above figure, the solution of VRP reveals that three vehicles (in three days) can cover the selected tourist spots (N2 to N21). After travelling two days, the third day may be planned for shifting from Agartala to Dharmanagar if the tourists entered in Tripura via flight. Alternatively, the second day may be reserved for shifting from Dharmanagar to Agartala if the tourists entered in Tripura via railway. The associated expenditure is calculated assuming a family of four people in any tourist group.

Table 5: Details of Expenditure to be incurred for hired cars after applying VRP

Vehicle	Route	Day	Distance (km)	Cost (INR)
V1	Agartala >>ChaturdashDevta Temple >>Baramura>>Neermahal>>Baxanagar>> Gomati Wildlife Sanctuary >>Chhabimura>>Sanaiya Waterfalls >> Agartala	Day 1	207	3070
V2	Agartala >>Khumulwang Eco Park >>Kasba Kali Temple >>Tepania Eco Park >>MahamuniPegoda>>Pilak Archaeological Sites >>Kalapania Nature Park >>Trishna Wildlife Sanctuary >> Agartala	Day 2	330	4300
Train Journey	Agartala to Dharmanagar [To and from]	Day 3	NA	1000
V3	Dharmanagar>>Rowa>>Unakoti>> Gomati Wildlife Sanctuary >Dumboor Lake >>Sanaiya Water Falls >> Eden Tourist Lodge >>Dharmanagar	Day 4	317	4170
Total		*4 days*	*854 km*	*INR 12540*

Comparing Tables 4 and 5, it is found that the tour can be completed in four days instead of six days if the planning is made applying VRP solution. Further, any single tourist party consisting of four members can save transportation expenditure by 35.5 % since travelling distance reduced by about 26.2 % along with a saving of two days night stay of hired car. Hence, it is an economic imperative for the tourist party to seek for cost minimization in transportation cost during the trip using the VRP.

V.CONCLUSIONS

This paper has attempted to apply the technique of Vehicle Routing Problem (VRP)to find optimal route for tourists to visit different tourist spots in Tripura. Normally, most tourists tour the state considering only one depot – Agartala. In this study, tourists or travelers are given the option for using two depots – Depot A (Agartala) and Depot B (Dharmanagar) which are well connected by railway. That is to say tourists may stay and start from any of the two depots. For instance, opting Depot B would enable one to tourN2, N3, N4, N5, N6 and even N14 instead of multiple travel from and to Depot A if Depot B is eliminated. This study applied the open-source spreadsheet solver developed by Erdoğan (2017). The optimal routes are identified considering distance travelled, driving time, and time spent at destination; and cost of travelling.

The overall solution to the VRP is associated with a cost of Rs. 12540 to cover 854 km of total distance travelled. In this process, total savings of distances travelled between the existing practice and proposed solution is 26.2% (288 km). Accordingly cost of transportation significantly reduces by 35.5% (INR 6880).

However, this study can further be extended by considering the requirement of tourist party separately as well as develop the model which can automatically determine the number of trip and type of vehicle requirement considering the type and capacities of the vehicle and requirements at each tourist spots.

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