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An Application of Goal Programming: The Best Route to Discover a Wonderful West Sumatera

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Abstract: This study presents an application of nonpreemptive goal programming to find the best route to visit tourist sites in West Sumatera. The goal programming model is constructed based on traveling salesman problem. This study involves seven cities which can be connected by road network in West Sumatera. In this study, two cases are considered with the assumption that the tourists start to self-drive from different city. The results show that the goal programming based on traveling salesman problem model gives a route with minimum distance, time, and traveling cost compared to the traditional route.

Keywords: Nonpreemptive Goal Programming, Minimum Distance, Self-Drive, Traveling Salesman Problem, West Sumatera

1. Introduction

West Sumatera, the homeland of Minangkabau tribal people, is one of the top-rated tourism places visited by tourists in Indonesia. West Sumatera situated in west coast of Sumatera Island is rich in natural beauty and unique culture. It has many different types of interesting tourist destinations and good tourism facilities such as road network and the accommodations. The increasing number of tourists can raise the regional income of West Sumatera.

One of the interesting tourism schemes in West Sumatera is self-drive tourism. Self-drive tourism can elevate the attractiveness of West Sumatera. Self-drive is traveling from home at least one night for holiday or visiting friends or relatives by driving their own or rented vehicle as the primary mode of transport [8]. Accessibility tourist destinations and good tourism facilities can support the self-drive tourism. The important feature of self-drive is that the tourists can choose their own route to visit the most wanted travel destinations, but they have to select the best self-drive route with minimum travel distance, cost, and time.

The best selection route problem has multiple objectives can be solved by goal programming. Goal programming was introduced by Charnes and Cooper [1] in 1955 is an extension of linear programming with multiple objectives. Shortest route optimization is a kind of Traveling Salesman Problem (TSP). TSP is the problem to find the shortest possible route that visits every destination exactly one and return to the first destination when the total distance is minimum. Jolai and Aghdaghi [5] use the goal programming technique for vehicle routing problems.

Hashim and Ismail [13] apply the preemptive goal programming for tourism route selection in Terengganu, Malaysia. Seely et al. [12] apply goal programming to aid the tourism planner in appraising the goal attainment potential associated with proposed tourism marketing program alternatives by changing priorities of goals, budgetary limitations, and organizational constraints. Gutin and Punen [3] write a book that provides the state of the art in theory and algorithms for the traveling salesman problem (TSP) that covers all important areas of study on TSP. Lau and McKercher [6] discusses the model of tourist movement self-drive patterns in a destination. Lew and McKercher [7] develop a tourist movement model using an inductive approach based on urban transportation modeling and tourist behavior. Yin et al. [10] develop self-drive travel and the broad field of the geographic information system (GIS) based on the self-drive tourists demand and supply. Hasan and

Halim [4] use goal programming to increase the tourist number and economy impact in Wetland Putrajaya Park.

This paper discusses an application of nonpreemptive goal programming based on TSP for the best self-drive route in West Sumatera, Indonesia. The tourists can visit several places in West Sumatera with minimum traveling distance, cost, and time.

2. Self-Drive Tourist Destinations in West Sumatera

In this section, the self-drive tourist destinations and problem definition in West Sumatera are presented. West Sumatera is selected for this study because it has a complete tourist attraction consisting of natural, historical, culture and shopping attractions. Natural wonder of West Sumatera is also very suitable to be seen by the tourists while they are self-driving around West Sumatera. The tourist will travel to seven cities in West Sumatera, namely Padang, Pariaman, Bukittinggi, Batusangkar, Padang Panjang, Solok and Payakumbuh.

During the self-drive tours, the tourist can visit 60 tourist attractions in 7 cities and stay at 9 hotels for 12 days and 12 nights. Tourists will visit Padang for 2 days, Pariaman for 2 days, Bukittinggi for 2 days, Batusangkar for 1 day, Padang Panjang for 1 day, Solok for 2 days and in Payakumbuh for 2 days. To simplify calculations, the self-drive tourism routes are divided into two parts, namely the route between hotels and 12 clusters of routes between tourist attractions. Each cluster consists of 1 hotel and 5 attractions. The number of clusters is the same as the number of tourist travel days. The visited tourist attractions and hotels in West Sumatera in this study are presented in Table 1 and Figure 1.

Table 1. *Self-Drive Destination in West Sumatera.*

Hotels / Homestays	Tourist Attractions	Abbreviation
	Pantai Padang (Padang Beach)	PP
	Pantai Pasir Jambak (Jambak Sand Beach)	PPJ
Brigitte's Houses (BRH)	Museum Adityawarman (Adityawarman Museum)	MA
	Bendungan Niagara Koto Pulai (Niagara-Like Dam in Koto Pulai)	BN
	Kota Tua (Old City)	KT
	Pantai Air Manis (Air Manis Beach)	PAM
	Gunung Padang (Siti Nurbaya Park)	GP
Brigitte's Houses (BRH)	Pantai Nirwana (Nirwana Beach)	PN
	Pasar Siti Nurbaya (Siti Nurbaya Traditional Market)	PSN
	Pelabuhan Teluk Bayur (Teluk Bayur Port)	PTB
	Pantai Gondoriah (Gondoriah Beach)	PG
	Pantai Arta (Arta Beach)	PA
Hotel Tazkia (HT)	Pantai Nareh (Nareh Beach)	PN
	Taman Anas Malik (Anas Malik Beach)	TAM
	Wisata Hutan Mangrove (Mangrove Forest Excursion)	WHM
	Wisata Sofa Angin (Air Sofa Excursion)	WSA
	Pantai Tiram Tapakis (Tiram Pakis Beach)	PTT
Hotel Tazkia (HT)	Pantai Cermin (Cermin Beach)	PC
	Makam Syeikh Ibrahim (The Great Islamic Scholar's Grave)	MSI
	Pantai Kata Pariaman (City of Pariaman Beach)	PKP
	Great Wall Koto Gadang	TC
	Lobang Jepang (Japanese Tunel)	LJ
De Cock Hotel (DC)	Jam Gadang (The Big Clock)	JG
	Museum Tri Daya (Tri Daya Museum)	TDE
	Istana Bung Hatta (Bung Hatta Palace)	IB
	Benteng Fort de Kock (Castle)	BFD
	Taman Margasatwa Kinantan (Kinantan Zoo)	TMK
De Cock Hotel (DC)	Museum Bung Hatta (Bung Hatta Museum)	MB
	Taman Ngarai Maaram (Ngarai Maaram Park)	TNM
	Tabing Takurung (Landscape)	TK
	Istana Pagaruyung (Minangkabau Historical Palace)	IP
	Negeri Tuo Pariangan (Old Village)	NTP
Hotel Pagaruyung 2 (HP)	Batu Batikam (Batikam Rock)	BT
	Benteng Fort van Der Capellen (Castle)	BFC
	Gedung Indo Jolito (Historical Building)	GIJ
	Pusat Kebudayaan dan Informasi Minangkabau (Minangkabau Culture Documentation and Information Center)	PDK
Wisma Alia Serambi	Masjid Asasi (Asasi Mosque)	MAS
	Lubuk Mata Kucing (Bath House)	LMK
	Stasiun Kereta Api (Historical Railway Station)	SKA
	Desa Pandai Sikek (Village with traditional weaving)	PS
	Puncak Thailand (Thailand Peak)	PUT
Hotel Palapa Prima (HPP)	Puncak Gobah (Gobah Peak)	PUB
	Pantai Tanjung Mutiara (Tanjung Mutiara Beach)	PTM

Hotels / Homestays	Tourist Attractions	Abbreviation
	Puncak Akasia (Akasia Peak)	PUS
	Puncak Cinangkiak (Cinangkiak Peak)	PUC
	Kebun Teh Alahan (Tea garden)	KTA
	Panorama Danau Kembar (Twin Lake)	DK
Penginapan Danau Diatas (PDA)	Bukit Cambai (Cambai Hill)	BC
	Danau Talang (Lake Talang)	DT
	Objek Wisata Yanti (Tourism place near lake)	WAY
	Kelok Sembilan (Twisted bridge 9)	KS
	Lembah Harau (Harau Valley)	LH
Ruqita Homestay (RH)	Kapalo Banda Taram (Bath House)	KBT
	Sarasah Tanggo (Waterfall)	ST
	Bukit Bulek Taram (Hill)	BBT
	Jembatan Ratapan Ibu (Historical Bridge)	JR
	Panorama Ampangan (Ampangan Panorama)	PAG
Ngalo Devilla (NDM)	Ngalau Indah (Cave)	NGI
	Rumah Sungai Baringin (Traditional and history house of Minangkabau)	RGB
	Padang Mangateh (Meadow)	PMA

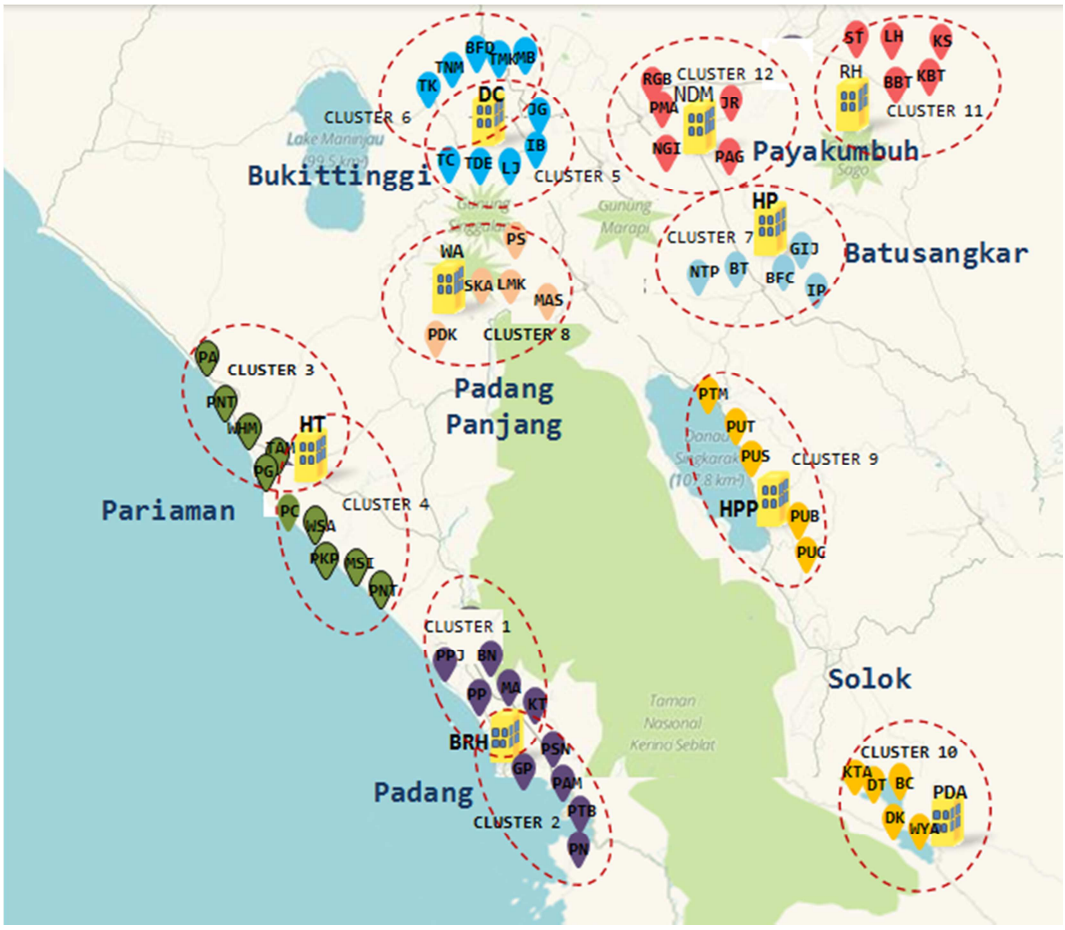

Figure 1. *Tourism Places Map in West Sumatera.*

The first place the tourists visit is Padang city. Of Padang here they start self-drive from Brigitte's House hotel. Each hotel on the route between attractions is the starting point for each cluster. The hotel selection is based on the cheap prices and close to tourist attractions. The distance and time data are obtained from the Google Maps Application. Meanwhile, the cost of traveling depends on the traveling distance and fuel prices. In this study, Pertalite, the vehicle fuel variant in Indonesia, is considered for the fuel at a price of Indonesian currency IDR7, 800/liter (1 liter can travel 10 km). The tourists will allocate 12 hours per day for traveling including the time to visit each tourist attraction for 2 hours and the time to drive for 2 hours.

In this study, it is assumed that there are two different cases based on the origin of tourists arrivals. The tourists come through Padang for case 1. They who come through Padang are those who come from outside West Sumatera and arrive at Minangkabau International Airport or the local residents of Padang. From Padang, they will drive with their own car or a rental car with the type of minibus and a rental

price of IDR300,000 per day, so that Padang is the starting city for case 1. Meanwhile, case 2 assumes that tourists come from neighboring Riau Province. The tourists begin to self-drive from neighboring Riau Province to Payakumbuh, so that Payakumbuh is the starting city of tourist trips for case 2. The first hotel that tourist visit in case 2 is Ruqita Homestay. The tourists from Riau could also bring their own vehicles or a rental car as for case 1.

3. Model Formulation

Ignizio [2] formulates the nonpreemptive goal programming model as follows:

$$\min\ z = \sum_{i=1}^{n} W_i(d_i^+, d_i^-)$$

Subject to

$$\sum_{i=1}^{n} a_{ij}x_j + d_i^- - d_i^+ = b_i\,,\ \text{ for } j = 1, 2, 3, \dots, n$$

$$x_j, d_i^-, d_i^+ \geq 0,\ \text{ for } i = 1, 2, 3, \dots, n$$

With x_j is the decision variable, d_i^+ is the positive deviation variable of the *i*th goal, d_i^- negative deviation variable of goal, a_{ij} is coefficient of decision variable, b_i is the aspiration level of the *i*th goal and W_i is the respective positive weights attached to these deviations in the achievement function.

According to the nonpreemptive goal programming model, a model for the tourist problem based on the TSP can be formulated as follows:

Decision Variables

The route problem in this case is the traveling salesman problem having binery decision variables

$$X_{ij} = \begin{cases} 1, \text{if the tourist traveled from } i \text{ to } j \\ 0, \text{others} \end{cases}$$

Notations

i: = original destination

j: = the next destination

n: = number of visited destination ($n = 9$ for hotel route and $n = 6$ for each tourist attraction route in the cluster)

p_{ij}: = traveling distance from destination i to j

c_{ij}: = traveling cost from destination i to j

t_{ij}: = traveling time to drive from destination i to j

u_i: = the sequence number of destination i on the trip

s_{ij}:= total traveling time to tour from destination i to j

d_1^+: = positive deviation variable for goal 1

d_2^+: = positive deviation variable for goal 2

d_3^+: = positive deviation variable for goal 3

S_{max}:= 9360 minutes for hotel routes and 720 minutes for tourist attraction routes

The Objective

Goal 1: Minimize the travel distance

Goal 2: Minimize the travel cost

Goal 3: Minimize the travel time to drive

Constraints

Constraint 1: The tourist does not exceed the maximum number of the trave day.

Constraint 2: The tourist must arrive in each destination i exactly once.

Constraint 3: The tourist must leave each destination j exactly once.

Constraint 4: No subroute is allowed.

Miller et al. [9] formulate the subtour elimination constraint as follows:

$$u_j \geq u_i + 1 - \left(1 - x_{ij}\right) n$$

Model Formulation

The nonpreemptive goal programming based on traveling salesman problem for the tourist problem can be formulated as follows:

$$\min z = d_1^+ + d_2^+ + d_3^+$$

Subject to

$$\sum_{i=1}^{n}\sum_{j=1}^{n} p_{ij}\, x_{ij} - d_1^+ = 0 \quad (1)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\, x_{ij} - d_2^+ = 0 \quad (2)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}\, x_{ij} - d_3^+ = 0 \quad (3)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} s_{ij}\, x_{ij} \leq S_{max} \quad (4)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad \text{for } j = 1, 2, \dots, n \quad (5)$$

$$\sum_{i=1}^{n} x_{ij} = 1, \quad \text{for } i = 1, 2, \dots, n \quad (6)$$

$$u_i - u_j + n\, x_{ij} \leq n - 1 \quad (7)$$

$$x_{ij}, d_1^+, d_2^+, d_3^+ \geq 0$$

Constraint (1) refers to goal 1 that the routes have minimum travel distance. Constraint (2) refers to goal 2 that the routes have minimum travel cost. Constraint (3) refers to goal 3 that the routes have minimum travel time. Constraint (4) makes sure the tourist does not exceed the number of maximum travel day. Constraint (5) and Constraint (6) make sure the tourist visit each destination exactly once. Constraint (7) is to avoid subroute tour.

4. Results and Discussion

The process of solving the model in the section 3 is carried out using LINGO 11. Schrage [11] says that LINGO allow a user to quickly input a model formulation, solve it, assess the correctness or appropriateness of the formulation based on the solution, quickly make minor modifications to the formulation, and repeat the process. The result of the proposed model of self-drive tourism in West Sumatera obtained by LINGO 11 is presented in Table 2.

Table 2. *The Short Self-Drive Tourism Route in West Sumatera.*

	Route
Hotel 1	BRH→PDA→HPP→HP→NDM→RH→DC→WA→HT→BRH
Hotel 2	RH→NDM→DC→WA→HT→BRH→PDA→HPP→HP→RH
Cluster 1	BRH→KT→MA→PPJ→BN→PP→BRH
Cluster 2	BRH→PSN→PN→PTB→PAM→GP→BRH
Cluster 3	HT→WHM→PA→PNT→TAM→PG→HT
Cluster 4	HT→PC→WSA→PKP→MSI→PTT→HT
Cluster 5	DC→JG→IB→LJ→TDE→TC→DC
Cluster 6	DC→TK→TNM→MB→BFD→TMK→DC
Cluster 7	HP→BT→NTP→BFC→IP→GIJ→HP
Cluster 8	WA→SKA→PS→LMK→MAS→PDK→WA
Cluster 9	HPP→PUC→PUB→PUS→PUT→PTM→HPP
Cluster 10	PDA→BC→DK→DT→KTK→WYA→PDA
Cluster 11	RH→BBT→KBT→KS→ST→LH→RH
Cluster 12	NDM→PAG→PMA→JR→RGB→NGI→NDM

Table 2 shows the best route for self-drive tourism in West Sumatera with minimum travel distance, cost and time. The hotel 1 and hotel 2 refer to the shortest route for case 1 and case 2. The order of the visited tourist attraction in the trip is dependent on the hotel route. For example in case 1, the tourist will visit Brigitte's House for the first time, so the cluster 1 is the first visited tourist attraction. The next day, tourist will visit the tourist attraction based on cluster 2 route. On the third day, the tourist travel to the next city, Solok, stay in Penginapan Danau Diatas and visit tourist attraction in cluster 10. That's how the trip to discover West Sumatera continues until the tourist return to Padang based on Table 2. The minimum traveling distance, cost, and time to drive are presented in Table 3.

Table 3. *Minimum Travel Distance, Cost and Time.*

Route	Distance (km)	Cost (IDR)	Time (minute)
Hotel	355.30	277,134	604
Cluster 1	46.55	36,309	112
Cluster 2	27.80	18,070	89
Cluster 3	35.40	27,612	61
Cluster 4	31.20	24,336	58
Cluster 5	3.35	2,613	12
Cluster 6	13.20	10,296	44
Cluster 7	35.60	27,768	67
Cluster 8	32.70	25,506	88
Cluster 9	56.80	44,034	115
Cluster 10	53.50	41,730	99
Cluster 11	67.50	52,650	131
Cluster 12	28.50	22,230	60
Total	784.40	610,288	1540

Based on the Table 3, the minimum traveling distance, cost and time are 787.4 km, IDR610,288 and 1540 minutes respectively for the self-drive traveling for 12 days in West Sumatera.

5. Conclusions

The results show the minimum traveling distance, cost and time for traveling in 7 cities in West Sumatera. The proposed goal programming based on TSP model give the suitable self-drive route for the tourist in this study. The proposed model helps the tourist to travel with minimum distance, cost and time involving 60 tourism destinations for 12 days. As a future development, improving the proposed model by adding some constraints is likely possible to do, like time windows for each tourist attraction and traffic problem.

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