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

Adhe Afriani, Habibis Saleh, Moh Danil Hendry Gamal*

Department of Mathematics, University of Riau, Pekanbaru, Indonesia

Email address: mdhgamal@unri.ac.id (M. D. H. Gamal)
*Corresponding Author

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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 once and return to the first destination when the total distance is minimum. Jolai and Aghdahgi [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.

| Hotels / Homestays       | Tourist Attractions                             | Abbreviation |
|--------------------------|-------------------------------------------------|--------------|
| Brigitte’s Houses (BRH)  | Pantai Padang (Padang Beach)                    | PP           |
|                          | Pantai Pasir Jambak (Jambak Sand Beach)         | PPJ          |
|                          | Museum Adityawarman (Adityawarman Museum)       | MA           |
|                          | Bendungan Niagara Koto Pula (Niagara-Like Dam in Koto Pula) | BN          |
|                          | Kota Tua (Old City)                             | KT           |
|                          | Pantai Air Manis (Air Manis Beach)              | TAM          |
|                          | Gunung Padang (Siti Nurbaya Park)               | WHM          |
|                          | Pantai Nirwana (Nirwana Beach)                  | WSA          |
|                          | 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          |
|                          | Pantai Cermim (Cermim 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 Tunnel)                  | LJ           |
|                          | Jam Gadang (The Big Clock)                       | JG           |
|                          | Museum Tri Daya (Tri Daya Museum)               | TDE          |
|                          | Istana Bung Hatta (Bung Hatta Palace)           | IB           |
| De Cock Hotel (DC)       | Benteng Fort de Kock (Castle)                    | BFD          |
|                          | Tamans Margasatwa Kinantan (Kinantan Zoo)        | TMK          |
|                          | Museum Bung Hatta (Bung Hatta Museum)            | MB           |
|                          | Tamans Ngarai Maaram (Ngarai Maaram Park)        | TNL          |
|                          | Tabing Takurung (Landscape)                      | TK           |
|                          | Istana Pagaruyang (Minangkabau Historical Palace) | IP           |
|                          | Negeri Tuo Pariangan (Old Village)              | NTP          |
| Hotel Pagaruyang 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
--- | --- | ---
Penginapan Danau Diatas (PDA) | Puncak Akasia (Akasia Peak) | PUS
| Puncak Cinangkiak (Cinangkiak Peak) | PUC
| Kebun Teh Alahan (Tea garden) | KTA
| Panorama Danau Kembar (Twin Lake) | DK
| Bukit Cambai (Cambai Hill) | BC
| Danau Talang (Lake Talang) | DT
| Objek Wisata Yanti (Tourism place near lake) | WAY
| Kebun Teh Alahan (Tea garden) | KTA
| Penginapan Danau Diatas (PDA) | KTA
| Danau Talang (Lake Talang) | DT
| Jembatan Ratapan Ibu (Historical Bridge) | JR
| Panorama Ampangan (Ampangan Panorama) | PAG
| Ruqita Homestay (RH) | Lembah Harau (Harau Valley) | LH
| Kapalo Banda Taram (Bath House) | KBT
| Sarasah Tagoon (Waterfall) | ST
| Bukit Bulek Taram (Hill) | BBT
| Ngalo Devilla (NDM) | Jembatan Ratapan Ibu (Historical Bridge) | JR
| 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 v ehicles 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

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

\[
x_j, d_i^-, d_i^+ \geq 0, \text{ for } i = 1, 2, 3, \ldots, n
\]

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 binary 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 \(j\)
\(d_i^+\): positive deviation variable for goal 1
\(d_i^+\): positive deviation variable for goal 2
\(d_i^+\): positive deviation variable for goal 3
\(S_{\text{max}}\): 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 travel 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:

\[
u_j \geq u_i + 1 - (1 - x_{ij}) n
\]

Model Formulation

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

\[
\min z = d_i^+ + d_i^+ + d_i^+
\]

Subject to

\[
\sum_{j=1}^{n} p_{ij} x_{ij} - d_i^+ = 0 \quad (1)
\]

\[
\sum_{j=1}^{n} c_{ij} x_{ij} - d_i^- = 0 \quad (2)
\]

\[
\sum_{j=1}^{n} t_{ij} x_{ij} - d_i^+ = 0 \quad (3)
\]

\[
\sum_{j=1}^{n} s_{ij} x_{ij} \leq S_{\text{max}} \quad (4)
\]

\[
\sum_{j=1}^{n} x_{ij} = 1 \quad \text{for } j = 1, 2, \ldots, n \quad (5)
\]

\[
\sum_{i=1}^{n} x_{ij} = 1, \quad \text{for } i = 1, 2, \ldots, n \quad (6)
\]

\[
u_i - u_j + n x_{ij} \leq n - 1 \quad \text{for } i = 1, 2, \ldots, n \quad (7)
\]

\[
x_{ij}, d_i^+, d_i^+, d_i^+ \geq 0
\]

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→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 1                | 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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