

Travel Planning Application: Combining Linear Programming and Shortest Route Problem to Optimize Travelers' Satisfactions

Athapol Ruangkanjanases and Phattharaphong Kaoian
Chulalongkorn Business School, Chulalongkorn University, Thailand.
athapol@cbs.chula.ac.th

Abstract—Travelers around the world use mobile applications to plan their holiday trips. However, none of the existing applications in the market is capable of optimizing satisfaction of a trip which travelers have different genders and various interests. This research proposes theoretical foundation for mobile application developers to create an application personalized for travel couples. A good trip for a couple is made of shared interests of both travelers. However, places and activities that are interesting for women may not satisfy men's interests and vice versa. Variables such as time, budget, stamina, satisfaction of a male traveler, and satisfaction of female traveler factors to the constraints of the trip. By using the variables as mentioned above, the model is developed with the objective to maximize satisfaction of the trip while balancing the interests of both genders. The shortest path models, both forward and backward routes, are combined with linear programming to set the constraints. The results of the simulation are applicable. The couple gets a solution for travel spots to visit, transportation route, money and time used for transportation, money and time used for visiting places, as well as the total satisfaction of both travelers.

Index Terms— Mobile; Travel; Application; Satisfaction; Gender; Linear Programming; Transportation

I. INTRODUCTION

Travel couples usually make their trips all year round. The destination can range from romantic places such as Paris, Venice, and Hawaii to the local and peaceful locations depend on their interests. Among travel trips in their lives, the honeymoon trip is one of the most memorable trips for most couples. More than 90% of newly married couples who choose traditional wedding goes for their honeymoon [1].

For the purpose of celebrating their marriage, the honeymoon trip can be considered as once in a lifetime trip. However, without good planning for the schedule, the trip could become a bad experience for the couples. Therefore, arranging the trip and considering many factors is essential to the planning of the honeymoon trip.

To start the plan, the targeted destination, duration of the trip and budget needs to be determined. After the honeymoon couples finalize where they are going to visit, they must draft all nearby travel spots, transportation modes, and accommodation. Lastly, they must choose the tourist attractions they will visit and plan the mode of transportation route, and then calculate their total expense.

However, in the actuality, planning the trip is not a simple task because there are be many places to be considered and factor constricting the decision making. With limited resources on their trip such as time, money and place

attributes [2, 3], many couples are facing the problem on which places they are going to visit and which route they should use. Also, the interest of each gender is different [4]. For example, women are most likely going to the historical sites and shopping areas while men prefer places with challenging nature-based activities [5, 6]. With the problem of satisfying the entire party with their needs, we propose the approach to utilize the linear programming and transportation model to solve the problems.

In this paper, the shortest path model is applied with modification on it to simulate the honeymoon trip schedule in day by day basis. Information needed for the model is time, money, stamina and satisfaction. For a time, the variables include time used in transportation from point to point and time used in visiting each place. For the money, the variables include the amount of money used for transportation modes and money used for visiting such as admission fees for each place.

Based on the information about the time spent on transportation and on visiting each place, the stamina is then calculated. This variable is set to make sure that within 1 day, the trip will not be too rush or spend too much energy on traveling. The last information required by the model is satisfaction. Each traveler is asked to rate his or her level of interest for each tourist attraction in the city based on 0 to 10 scores. So, the satisfaction value represents how strong each traveler wants to visit each travel spot. The satisfaction value of 0 means extremely uninterested to go to that place and the value of 10 means extremely interested to go to that travel spot.

By using the shortest path algorithm, together with linear programming, the model calculates the route used in the trip and places to visit with respect to the constraints set on time, budget, and stamina of each day. The goal of the model is to maximize the satisfaction score of the travelers while balancing the needs of the male and female travelers in the appropriate range.

II. MODEL ASSUMPTION AND NOTATION

The model proposed in this research paper is derived from the shortest path model [7-10] and linear programming [11]. The equation set by the linear programming aims to maximize the satisfaction of the honey couple based on the limited resource available. The objective function and the constraints could be written as equations shown as follows:

Objective function:

$$\text{Max } Z = \text{Total Satisfaction of a couple} \quad (1)$$

Constraints:

$$\text{Total budget or Time} \leq \text{Resources available} \quad (2)$$

For the travel route, the shortest path model is applied. The model utilizes the node diagram, in which the node can refer to the travel spot, and the path connecting the node is the transportation between each of the node. For each of the path, there is a weight which refers to the distance between 2 nodes, and the total number of paths going in is equal to the total number of paths going out at each node. The key to this model is to find the travel path between 2 nodes with the shortest distance.

With constraints set by linear programming and the travel path derived from the shortest path model, the solution will be the travel schedule based on the couple's resources and interests. However, based on the normal shortest path model as shown in Figure 1, there is a limitation that the route should only be going forward to the end node only [7, 12]. For example, at node i, the incoming path is from node k only, and the outgoing paths are to node j and node n. With this logic, the couple needs to travel from one place to another place every day and could not stay in one place for a long period of times.

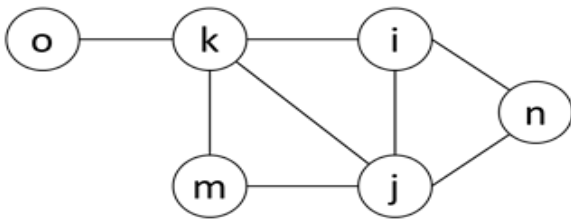


Figure 1: Node diagram of a normal shortest path model

Therefore, the double shortest path model is developed; with one model represent the forward path and another represents the backward path. The proposed model can be made into the node diagram by adapting from Figure 1 into Figure 2. There are assumptions that support the model to function:

1. The model is used for day to day basis trip.
2. The shortest path model using here comprises of 2 parts: forward route and backward route.
3. The forward route is for the path going to the right or down (all node with no hyphen and its connecting path).
4. The backward route is for a reverse path back to the origin point, the node is depicted with a hyphen (e.g. k').
5. The forward and Backward route connected from point-to-point depicted in Figure 2, in which this path can be from forward to backward route only.
6. The couple can visit the node on either forward or backward route, but the travel spots can be visited only 1 time.
7. To travel to each place, there must be at least one route to go to that node (excluding the route connecting forward and backward node diagram).

8. Assume that the travelers are 1 man and 1 woman and are traveling together.
9. Constraints using here are time, budget, stamina, and satisfaction of man and satisfaction of woman.

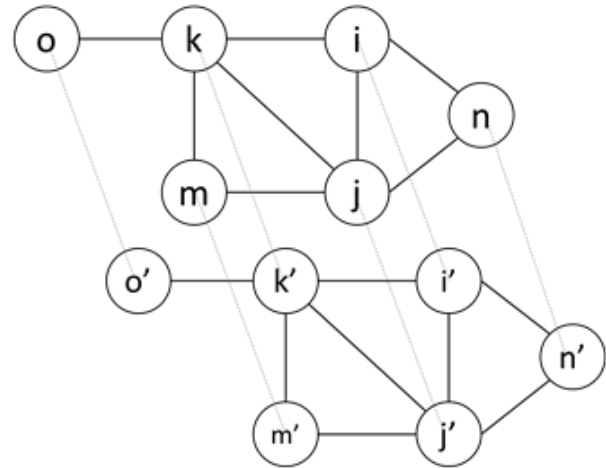


Figure 2: Node diagram of proposed shortest path model (forward and backward route)

The node diagram in Figure 2 shows that the backward route is similar to the forward route in terms of the connection. However, the direction of the path is different. For the forward route, the direction of the path is from left to right and going backward is not allowed. On the other hand, the backward route starts from right to left. These 2 routes are connected by node-to-node. So, at node i', the incoming path is from node i, n', and j', with the outgoing path to node k' only.

For each node and path, the variables are defined as follows:

- R_{ij} = Route from node i to j (0= not use this route, 1 = use this route)
- X_i = traveler visiting node i (0= not visit, 1 = visit)
- TT_{ij} = Time used in travel from node i to j
- TV_i = Time used in visiting node i
- M_{ij} = Money used in travel from node i to j
- M_i = Money (if) used in visiting node i
- S_{ij} = Stamina used in travel from node i to j
- S_i = Stamina (if) used in visiting node i
- SM_i = Satisfaction of Male in visiting node i
- SF_i = Satisfaction of Female in visiting node i

The key variable for the model is X_i , as the variable “ X_i ” is set as the linkage between the linear programming and the shortest path model. The variable X_i indicates that the couple will visit each node i or not. If the place at node i is to be selected, the value of X_i will be 1. If not, the value will be 0. For X_i , even the value equals 0, the route can still pass through this node without visiting. First, we set the main objective of the model to get the most satisfaction from this trip by multiplying the satisfaction value for each place for man and woman to the variable X_i as the following equation:

$$\text{Objective function: Maximize } Z = \sum_{i=1}^n SM_i X_i + \sum_{i=1}^n SF_i X_i \quad (3)$$

As mentioned earlier that the satisfaction values of each travel spot are scored independently by male and female travellers. For example, a honeymoon trip in Tokyo, a male traveller might give the score of 5 for the level of interest in visiting the Imperial Palace while the female traveller might give the score of 9 for this place. On the other hand, for the level of interest of Akihabara Electronic Devices Market, the male traveller might give a score of 10 while female traveller might not be interested and gives a score of 3. Even though the model's objective is to maximize the overall satisfaction scores, the balance of interests among travellers is also important. The total satisfaction of male and female travelers should not be too far apart. Therefore, the total satisfaction scores (sum of the level of satisfaction scores for all spots visited) for each traveler should not be too far apart subject to the constraint equation below;

$$\left| \sum_{i=1}^n \text{SatisfactionMale} - \sum_{i=1}^n \text{SatisfactionFemale} \right| \leq \text{SettingValue} \quad (4)$$

This setting value in equation (4) can be adjusted based on the preference of each honeymoon couple. Then, there are constraints on time, budget and stamina for both transportation and visiting each place, the equations can be written as follows:

$$\sum_{i=1}^n \sum_{j=1}^m TT_{ij} R_{ij} + \sum_{i=1}^n TV_i X_i \leq \text{SettingTIME} \quad (5)$$

$$\sum_{i=1}^n \sum_{j=1}^m M_{ij} R_{ij} + \sum_{i=1}^n M_i X_i \leq \text{SettingBUDGET} \quad (6)$$

$$\sum_{i=1}^n \sum_{j=1}^m S_{ij} R_{ij} + \sum_{i=1}^n S_i X_i \leq \text{SettingSTAMINA} \quad (7)$$

These equations need to be solved together with the shortest path model. Based on shortest path model, the equation can be explained as a total of the path going in equal to the total of the path going out. Therefore, the equation at any node will be:

$$\sum_{i=1}^n \sum_{j=1}^m R_{ij} - \sum_{i=1}^n \sum_{k=1}^p R_{ki} = 0 \quad (8)$$

where node j is next node to node i and node k is the previous node to node i.

For the proposed model, as each node in the forward route will have another path connected to the backward route [10], equation at each node of the forward route (node with no hyphen) can be derived as follows:

$$\text{Forward route: } \sum_{i=1}^n \sum_{j=1}^m R_{ij} - \sum_{i=1}^n \sum_{k=1}^p R_{ki} + R_{ii} = 0$$

$$\text{Therefore, at node i: } R_{ij} + R_{ii} - R_{ki} = 0 \quad (9)$$

The equation for the backward route (Hyphen node) is as

follows:

$$\text{Backward route: } \sum_{i'=1}^n \sum_{j'=1}^m R_{i'j'} - \sum_{i'=1}^n \sum_{k'=1}^p R_{k'i'} - R_{ii'} = 0$$

$$\text{Therefore, at node j': } R_{j'i'} + R_{j'k'} - R_{jj'} = 0 \quad (10)$$

For the starting and finishing node, there must be a path going out and a path going in respectively. Thus, the equation of the path at these nodes will be:

$$R_{\text{Starting/Finishing}} = 1 \quad (11)$$

At each node, if travelers were to visit node i (Xi equals to 1), there must be at least one path coming into the node i. So, if there are many paths coming into node i, the equation will be:

$$X_i \leq \sum_{i=1}^n \sum_{k=1}^p R_{ki}; \text{ for each node} \quad (12)$$

where k means any node that comes before node i.

Lastly, as the couple can visit the node either on forwarding or backward route, we need to set the constraint as well to prevent this case to happen (otherwise 1 place could be visited 2 times). We set the summation of Xi and Xi' must be no more than 1 to prevent this scenario.

$$X_i + X_{i'} \leq 1; \text{ for all node} \quad (13)$$

By solving all equations and constraints, the model will calculate the route and travel spots to visit, to get the total satisfaction for the honeymoon couple on this trip.

III. EQUATIONS AND CALCULATIONS

From the node diagram in Figure 2, the diagram was modified. The starting point node was added at node H (Hotel). Therefore, the starting point will be from node H and end at H' (or start and finish at the hotel) as shown in figure 3. This starting point is set to make the equation easier to solve due to the path coming out of the starting point is only 1 path. However, the model can set any node to be the starting point. To set the different starting point, one must take into account all possible paths branching out from the starting point.

The routing equations from and to the hotel are written as follows:

$$\text{Node H: } R_{H-1} = 1 \quad (14)$$

$$\text{Node H': } R_{1'-H'} = 1 \quad (15)$$

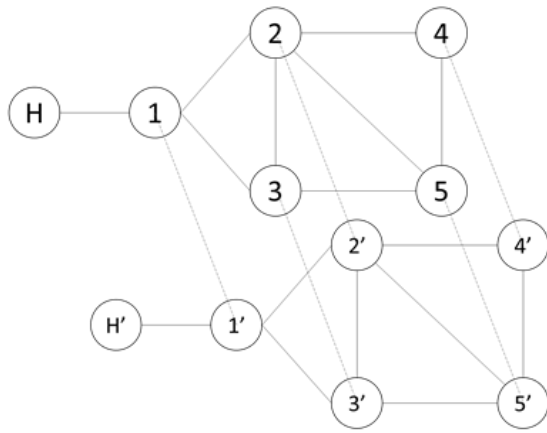


Figure 3: Example of node diagram

For the remaining nodes, the equation for each node can be written as follows:

$$\text{Node 1: } R_{1-2} + R_{1-3} + R_{1-1'} - R_{H-1} = 0 \quad (16)$$

$$\text{Node 1': } R_{1'-H} - R_{1'-1} - R_{2'-1} - R_{3'-1} = 0 \quad (17)$$

$$\text{Node 2: } R_{2-3} + R_{2-4} + R_{2-5} + R_{2-2'} - R_{1-2} = 0 \quad (18)$$

$$\text{Node 2': } R_{2'-1} - R_{2'-2} - R_{3'-2} - R_{4'-2} - R_{5'-2} = 0 \quad (19)$$

$$\text{Node 3: } R_{3-5} + R_{3-3'} - R_{1-3} - R_{2-3} = 0 \quad (20)$$

$$\text{Node 3': } R_{3'-1} + R_{3'-2} - R_{3'-3} - R_{5'-3} = 0 \quad (21)$$

$$\text{Node 4: } R_{4-5} + R_{4-4'} - R_{2-4} = 0 \quad (22)$$

$$\text{Node 4': } R_{4'-2} - R_{4'-4} - R_{5'-4} = 0 \quad (23)$$

$$\text{Node 5: } R_{5-5'} - R_{2-5} - R_{3-5} - R_{4-5} = 0 \quad (24)$$

$$\text{Node 5': } R_{5'-2} + R_{5'-3} + R_{5'-4} - R_{5-5'} = 0 \quad (25)$$

All the equations above are used to calculate the route in this trip. For route from node A to A' (RA-A'), the time, money and stamina using will be zero as this route do not exist, but only used in this model to support the purpose of having the same start and finish node. Also, for traveling to each spot or node, the equations are as follows:

$$\text{Node 1: } X_1 \leq R_{H-1} \quad (26)$$

$$\text{Node 2: } X_2 \leq R_{1-2} \quad (27)$$

$$\text{Node 3: } X_3 \leq R_{1-3} + R_{2-3} \quad (28)$$

$$\text{Node 4: } X_4 \leq R_{2-4} \quad (29)$$

$$\text{Node 5: } X_5 \leq R_{2-5} + R_{3-5} + R_{4-5} \quad (30)$$

$$\text{Node 1': } X_{1'} \leq R_{2'-1} + R_{3'-1} \quad (31)$$

$$\text{Node 2': } X_{2'} \leq R_{3'-2} + R_{4'-2} + R_{5'-2} \quad (32)$$

$$\text{Node 3': } X_{3'} \leq R_{5'-3} \quad (33)$$

$$\text{Node 4': } X_{4'} \leq R_{5'-4} \quad (34)$$

For each node, it can be visited only 1 time, so the equations are as follows:

$$\text{Node 1/1': } X_1 + X_{1'} \leq 1 \quad (35)$$

$$\text{Node 2/2': } X_2 + X_{2'} \leq 1 \quad (36)$$

$$\text{Node 3/3': } X_3 + X_{3'} \leq 1 \quad (37)$$

$$\text{Node 4/4': } X_4 + X_{4'} \leq 1 \quad (38)$$

$$\text{Node 5/5': } X_5 + X_{5'} \leq 1 \quad (39)$$

All these equations are used in linear programming as constraints. By combining these equations with other constraints (stamina, time, money), we will be able to determine which route will be used and which nodes will be visited. For the stamina, the value of stamina used in traveling from node i to node j is calculated based on the amount of time spent in traveling from node i to node j. In addition, the stamina value used in visiting node i is calculated based on the amount of time spending at node i. The equations are displayed as follows:

$$S_{ij} = TT_{ij} / 10 \quad (40)$$

$$S_i = (TT_i / 10) + 5 \quad (41)$$

The equations were formulated from the idea that the total time spent in 1 day to travel and visit places is 10 hours or 600 minutes (excluding time spent on having meals such as lunch and dinner which takes an average of 1 hour each). Then the equations for calculating the stamina were set up. Total stamina spent within 1 day will be less than 100 points.

An example of the data on transportation and sightseeing in each node is indicated in table 1. The constraints on budget and time spent per day are set to be 1,100 Yen and 400 minutes for traveling time. Stamina cannot be more than 100 points and the difference in satisfaction between each gender is set to be no more than 10. The simulation result of the transportation is illustrated in figure 4.

The result shows that the travelers will visit place number 1, 2, 3, and 5 and only pass-by place number 4. The results show that the total budget will be 1,080 Yen, total time spent is 348 minutes and total satisfaction will be 42 points (21 points for male and 21 points for female).

Table 1
Information on node data and its route

Node i (place)	Time spent at this place (Minutes)	Money used if visiting this place (Yen)	Satisfaction		Route to Node j	Time if travel from node I to node j	Money used if travel from node I to node j
			Male	Female			
H	-	-	-	-	1	3	0
1	75	70	1	8	2	10	150
					3	15	120
					3	13	200
2	60	100	7	4	4	19	170
					5	20	300
					-	-	-
3	90	60	9	2	5	17	220
4	60	80	2	6	5	16	100
5	40	90	4	7	-	-	-

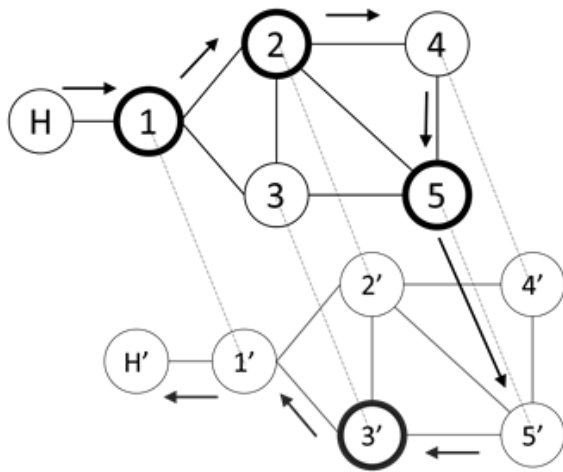


Figure 4: Route and places to visit from simulation

IV. APPLICATIONS AND ILLUSTRATIONS

The model proposed in this article can be applied to many applications. For example, the model is utilized for planning the couple's trip to Japan. The reason for choosing Japan is that Japan is one of the most popular countries for travelers. The most inbound city arrival in Tokyo [13]. At Tokyo, as a capital city of Japan, there are many places to visit, with

varieties in each sightseeing spot; ranging from historic temples, palaces, shopping areas, parks, architectural buildings, and skyscrapers. With many tourist attractions, the city is linked by many rail routes. The information on transportation, especially the train system used in this illustration can be downloaded from the Japan Railway website [14]. The assumption is that the trip will be around Tokyo city only. The hotel is fixed in one place. The hotel accommodation fee, as well as food and beverages expenses, are excluded from the model.

For Tokyo, the main train route is the Yamanote-line which is the loop line around Tokyo. So, the sightseeing spots that are close to the Yamanote-line are the targets. Next, the main tourist attractions in Tokyo which can be accessed easily by Yamanote-line, and those not too far from the main train route (such as Tokyo tower or Asakusa temple) are focused. For the accommodation, the hotel spot outside of Shinjuku station was selected. It takes 15 minutes from the hotel to Shinjuku station. After all the travel spots were listed, the train route to connect and make a node diagram can be shown in figure 5. The information on travel spot, train route, stamina, and satisfaction is shown in table 2. For the transportation time, the information came from the Japan rail website [14]. Time traveling from node i to node j shown in table 2 are the average time including waiting time for each train.

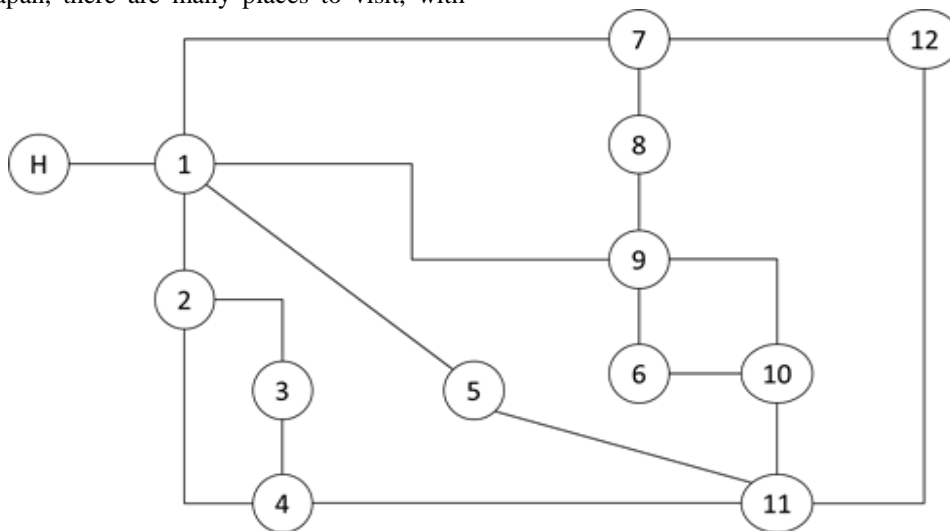


Figure 5: Node diagram for the travel spot in Tokyo

Table 2 displays information on each of node i such as location, expenses, time and details to move from node i to its next node only. To move further than that, the actual time traveling spent will be added on. For example, to move from node 1 to node 3, the model will calculate from node 1 to node 2 and then node 2 to node 3. For the information on the satisfaction, the assumption in the case is that a woman would prefer shopping more than sightseeing and a man would be opposite.

Based on the information on node diagram and the information on the train route, Excel Solver was used to optimizing total satisfaction of the honeymoon trip. By setting the objective to maximize the satisfaction of the couple, the optimized travel route, and the traveling spots to visit as shown in figure 6. This day trip will start from hotel to node 7, 12, 11, 10, 6, 9 and go back to the hotel. The total time spent is 462 minutes, expense at 4,700 yen, with the

stamina consumption at 76.2 points. For the satisfaction level, the total satisfaction is at 68 points (34 points for male and 34 points for female).

From the results, there is still some time left in the day trip, therefore the couple could spend a little more time on each travel spot. Alternatively, they could change the duration of time visiting each place to be shorter and run the simulation again. So, they might be able to visit more places for the new result.

Furthermore, the model could handle the honeymoon trip planning and can be adjusted to match with each couple by changing the setup values of satisfaction of male, the satisfaction of female, time spent at each of the travel spots. By adjusting any of the parameters, the result of the simulation will change according to the couple's needs and interests.

Table 2
Information on the node for Tokyo and its transportation route

Node i	Place (Location Name)	Time spent at this place (minutes)	Money used when visiting this place (Yen)	Satisfaction		The route to node j	Time traveling from node i to j (minutes)	Money used in travel from node i to j (Yen)
				Male	Female			
H	0	0	0	0	0	1	15	250
1	Shinjuku	60	1200	6	6	2	6	140
						5	7	220
						9	16	200
2	Harajuku	75	1100	6	9	3	4	170
						4	4	140
3	Omote-sando	45	1500	3	8	4	4	170
4	Shibuya	100	900	4	10	11	21	200
5	Tokyo Tower	60	2000	7	5	11	15	180
6	Imperial Palace	45	500	6	4	10	15	0
7	Ueno	90	1000	8	8	8	5	140
						12	7	170
8	Akihabara	80	1200	10	3	9	5	140
9	Tokyo	40	750	6	5	6	15	0
						10	4	140
10	Ginza	60	400	4	7	11	6	140
11	Shimbashi	30	0	2	4	12	17	220
12	Asakusa	65	600	8	6	-	-	-

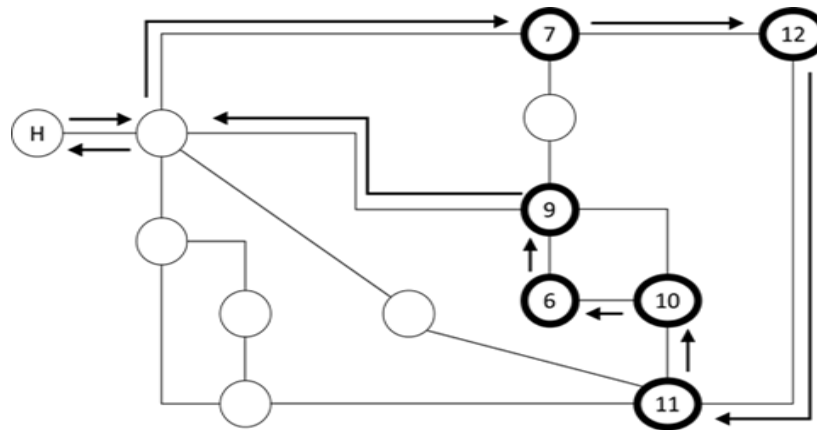


Figure 6: Result from simulation on a day-to-day trip in Tokyo

V. CONCLUSION AND DISCUSSION

In this paper, the travel planning application for the couples is demonstrated by utilizing the shortest path algorithm and linear programming. To maximize the total satisfaction of this trip while the balancing the interests of both genders, 2 shortest path models, forward and backward route are combined with linear programming. The results of the simulation are applicable. The traveling couple gets solutions for travel spots to visit, transportation route, money and time used for transportation, money and time used for visiting places, as well as the total satisfaction of both travelers.

However, further study is needed for more realistic model. The point that needs to be developed is the selection of the accommodation locations which will affect the route, budget and time spent in each day as each couple may select the hotel from how far it is from the main attraction, the budget they have, or the hotel’s surroundings such as shops and scenery. Moreover, this model still has a limitation on the path selection as the route can only go one way in each forward and backward route, and the path connecting forward and backward can only go one way as well. Therefore, the next developed model should consider these issues. Furthermore, an extension of this model can be developed to apply for trip planning for a group of 3 travelers or more.

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