A Decision Support System for Urban Journey Planning in Multimodal Public Transit Network

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Abstract:
The goal of this paper is to develop a Decision Support System (DSS) as a journey planner in complex and large multimodal urban network called Rahyar. Rahyar attempts to identify the most desirable itinerary among all feasible alternatives. The desirability of an itinerary is measured by a disutility function, which is defined as a weighted sum of some criteria. The weights represent travelers’ preferences to the attributes (e.g., total travel time and monetary cost). The journey-planning problem in Rahyar is developed as a multi-destination, multi-criteria shortest tour problem with time windows. This problem is one of the important and practical problems in several fields including transportation. This problem is structured based on a Traveling Salesman Problem with Time Windows (TSPTW). Three modes of walking, bus, and subway are assumed to be used for traveling between points. It is demonstrated that Rahyar is capable of effectively generating alternative itineraries for a tour that involves multiple trips and multiple modes, with complex constraints. The planner serves as a practical tool for travelers in itinerary planning.

Keywords: Journey Planning, Multimodal Transportation, Time windows, Decision Support System, Multi-Destination Trip, Public Transportation.

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1. Introduction

Transportation is the movement of people and goods from one point of activity to the other. It is socially and economically the backbone for the development of a city. As cities enlarge in size, the total travel time and the number of trips also increase. As the city becomes much extended, the city center becomes congested. In such a situation and without the provision of an efficient public transport, people tend to rely on private cars (Gwilliam, 2002).

Multimodal transportation systems are public, ordinary networks in urban areas, particularly in metropolises where the citizens may utilize a combination of several modes of transportation such as personal car, taxi, subway, tram, bus, and walking. Using a combination of these networks leads to saving travel time and cost for citizens, and reduces traffic jams and air pollutions, greatly assisting sustainable development of metropolises (Abbaspour & Samadzadegan, 2010).

Movement is restricted by available time and the travel speed. Hence, it is important to organize journeys in an efficient manner such that the time resource can be best utilized to engage in other activities. One way to achieve this goal is by developing efficient journey plans.

Therefore, the aim of this paper is to develop such a Decision Support System (DSS) called Rahyar that helps the traveler in using public transit in a complex networks, so that multiple locations are visited with user preferences and constraints.

Rahyar Journey Planner is the computer software that assists the traveler by proposing efficient itineraries for visiting multiple locations using alternative travel modes. Given a set of locations, Rahyar develops alternative journeys for the visits interactively with the traveler, based on the preferences and constraints.

There are a few features embodied in Rahyar that are not found entirely in the existing trip planners. The first is multi-criteria, as some of the existing trip planners are not capable of dealing with more than one criterion simultaneously. The second is multimodal. The third is adjusting preference weights to meet different user needs at different times, and the last one is, multi-destination in journey planning. Furthermore, the software has the ability to save the itinerary data. This feature makes the planner more flexible and also enables the user to make changes in her/ his preferences or visits during trip.

The paper is organized as follows. In Section 2, a literature review and a summary of existing trip planners in both public and private domains are presented. The components of Rahyar are described in Section 3. Section 4 offers a mathematical model of traveling salesman problem used in Rahyar. In Section 5, Tehran Public transit network will be studied as a case and a sample itinerary plan will be provided based on assumed locations, constraints and preferences. The conclusions of this study are presented in Section 6.

2. Literature Review

Public transit systems play an important role in transporting travelers in metropolitan areas (Li et al. 2010). Transit user’s characteristics are origin, destination and expected departure or arrival time. Based on the scheduled provided by transit agencies, the transit users need to choose the routes and transfer stations that can appropriately fit their travel needs. However finding appropriate travel routes manually is complicated, mainly because it is difficult to determine proper transfer points between different routes. The complexity of finding a multimodal route is much higher than for a mono-modal one (Abbaspour & Samadzadegan, 2010). In the multimodal networks, several modes of transportation operate concurrently under the changing conditions. Multimodal route planning in the transportation field provides the user with an optimal route between the source and the target of a trip, which may involve several different transportation modes (Homechair, 2008). Another research describes the requirements of a multimodal transportation routing system in more detail (Rehr et al., 2007). Zhang et al. (2015) employs uncertain programming to investigate the uncertain multi-modal shortest path problem. In this paper, the uncertain variables are characterized by the arc travel time and arc travel costs related to different transport mods. Liu et al. (2014) investigate the algorithms of the multi-modal shortest path problem (M-SPP) under static and certain environment and their extension in urban transit network. In this research, an improved exact label setting algorithm. Due to progress of computing, communication and storage technologies, automatic transit trip planners have been implemented in recent years (Power, 2007). Recent
enhancements include added input capabilities, output capabilities, mapping capabilities, and multimodal integration (Watkins et al., 2010). Transit trip planners accept the origin, destination and expected departure/arrival time input from users and find proper routes using available transit services.

Transit trip planners are generally web-based (Li et al., 2010). In the development of a trip planner, a decision support tool for trip planning is not a new idea. Many trip planners had been developed before the development of the itinerary planner of this study. Some notable transit trip planners include Bay Area Transit Planners, Google Transit Planner, Houston MTA Transit Planner, Los Angeles Metro Transit Planner, New York City Transit Planner, Seattle Metro Transit Planner, and Deutsche Bahn and Transport Direct. Some researchers have also proposed transit trip planners (Peng & Huang, 2000; Jariyasunant et al., 2009). Peng et al. (2005) also give a survey on transit trip planner software.

Cherry et al. (2006) implement an Arc IMS GIS-based itinerary planner for Sun Tran in Tucson that allows users to select origin and destination on a map, in addition to traditional manual address entry or pull-down landmark menus. Others attempt the integration of two completely independent trip planners using a broker that divides the trip between the two systems and assembles the answer for the user. Another system is developed and tested for the trip planners in greater Waukesha and Milwaukee, Wisconsin (Peng & Kim, 2008).

More recently, several cities, including Atlanta, London and Athens, have developed multimodal trip planners. The Regional Transportation Authority’s Goroo trip planner includes the option to obtain directions for train, bus, driving and drive to bus, comparing the distance, time, cost and carbon output of the trip for the modes queried. The A-Train in Atlanta and Transport for London already include cycling and walking routes in their transit trip planners. In Athens, an urban trip planner has been combined with countrywide coach, air, and ferry service (Zografos & Androutsopoulos, 2008)

3. Components of Rahyar system

Rahyar is designed to construct an itinerary that is suitable for engaging in a series of activities at different locations. It is a multimodal planning system with public transit databases and accounts for users’ preferences and constraints as it interactively builds an itinerary. An itinerary here comprises a set of sequenced activity locations to visit and trips, which connect these locations. Rahyar considers a set of trip attributes (e.g., travel time, distance, waiting time, etc.), while identifying the best itinerary for the user.

As illustrated in figure 1, Rahyar consists of four major components: (1) Infrastructure Manager, (2) User Input Manager, (3) Journey Optimizer and (4) System Output Manager. Because the network/mode data may change during time, there should be a platform, which facilitates application of these changes into database. Hence, Infrastructure Manager is a component, which the system administrator could use to update network/mode data. In addition, the user must introduce visiting locations, preferences and constraints. Therefore, another component, named User Input Manager is designed to gather such information. The input information is fed into the

![Figure 1- Rahyar components](image-url)
Journey Optimizer, which analyzes the input information, evaluates all possible itineraries and computes preference scores using initial preference weights for the respective trip attributes. One alternative itinerary with highest preference scores is then selected by the Optimizer and presented to the user. This constitutes the outputs to the user.

Figure 1- Rahyar components

3-1 Infrastructure Manager
As in any DSS software in which some dynamic/static data are used to solve the desired problem, Rahyar also has a database in which the public transit network and each node/arc attribute may change and the related changes must be applied in Rahyar database. Therefore, the Infrastructure Manager is designed to administer such activities and if any changes occur in infrastructure data, the administrator can update the related data.

The data requirements of this component include static network data, dynamic network data, transit specific data (such as time schedules, routes, network coverage) and landmark geo-reference data.

3-2 User Input Manager
As described above, this component is designed to gather user preferences, constraints and visiting locations. Journey Optimizer uses such information to form the desired itinerary. The inputs from the user define a specific itinerary development problem.

The user inputs to the Optimizer comprise of
* the initial and final locations,
* the set of locations to be visited,
* anticipated duration of stay at each location,
* constraints on the sequence of the visits,
* constraints associated with the timing of each visit, and
* available travel modes and preferences toward alternative modes.

The location of a visit is considered as hard, if it is a specific place where the activity is to take place, and is considered as soft, if it is one of the alternative locations where the activity can be pursued. In case of hard locations, their exact geographical locations are to be provided by the user. Soft locations can be thought of as a set of opportunities such as grocery stores. The Optimizer generates a set of opportunities. Rahyar journey planner is set up to deal only with hard locations. The user can specify hard locations by either giving the exact address or clicking on the map. Although adding Soft location to the Planner could leverage the software value and usability, but because of inaccessibility to related data, soft locations were surrendered in planning procedure.

Timing constraints refer to the time windows associated with a visit, when the user wishes to arrive at the ith location no earlier than \(a_i\) and no later than \(b_i\). The time window of the visit is expressed as \((a_i, b_i)\). Complexity of timing constraints increases when the user wishes to arrive at and leave the ith location within certain intervals. In this case, the time windows can be expressed as \((c_i, d_i); (e_i, f_i))\). The arrival at, and the departure from the ith location can take place only during intervals of \((a_i, b_i)\) and \((c_i, d_i)\), respectively. Only time constraints with a single time window are dealt with Rahyar. Nevertheless, as indicated in fig 7, Because in addition to arrival time, Visit time is considered in planning procedure, automatically departure time window is considered.

The duration of a visit at the ith location may be subject to upper and/or lower bounds: \((d_{li}, d_{ui})\). For instance, the user may want to shop for no less than 10 minutes \((d_{li})\) as the minimum duration at ith location, but no more than 2 hours \((d_{ui})\) as the maximum duration at ith location. It should be noted that \((d_{li}, d_{ui})\) is different from \((a_i, b_i)\) or \((c_i, d_i); (e_i, f_i))\) described above; \((d_{li}, d_{ui})\) refers to time length, while the latter cases refer to the time of day.

Constraints on the sequence of visits arise from one of the following incidents: (1) visit A must be made before or after visit B, (2) visit A must be the first or the last to be made, and (3) there must be a certain number of visits to be made between visits A and B. Only the first type of sequence constraints is considered in Rahyar.

Mode constraints may be static or dynamic. Static constraints refer to those that do not change along the course of an itinerary. For example, the user may have no access to a particular travel mode; or the user does not consider taking a certain mode, even though it is available. These constraints can be specified at the outset of an itinerary development session with Rahyar. Dynamic constraints come into effect because of various conditions that arise or vanish as an itinerary evolves. For example, if a trip is made outside the operating hours of public transit, then public transit is not available for the trip. Modal constraints may also lead to constraints on visits. The user identifies stationary constraints, while dynamic constraints...
straints are identified and incorporated into the itinerary development process automatically by Rahyar. The user indicates when and where he/she wishes to start and end the entire trip.

3-3 Journey Optimizer

Figure 2, the flowchart of the itinerary planning, illustrates how Rahyar functions. In Step 0, the level one transit network is created based on available transit modes and service lines.

In Step 1, the user supplies information on locations to visit, constraints associated with each visit, mode preferences, etc. In Step 2, the Optimizer locates the nearest nodes to the activity locations selected by the user and add related arcs to create the level 2 transit network. In Step 3, the Journey Optimizer finds the shortest path between every possible pair of visiting locations based on selected criteria. In Step 4, the Journey Optimizer finds the shortest sequence of visiting locations. In Step 5, the Journey Optimizer computes travel time for each visiting location and calculates the time needed for each travel. In Step 6, the Journey Optimizer checks the feasibility of the itinerary against the constraints given by the user. If the itinerary is feasible, in Step 7, the Optimizer will compute itinerary attributes; otherwise, Steps 4 to 6 will be repeated and the next shortest sequence will be cho-

Step 0: Create Level 1 network based on available modes and service lines.

Step 1: User inputs locations to visit as well as constraints, preference weights and desired time windows, via user Input Manager.

Step 2: Journey Optimizer locates the nearest nodes to the points selected by the user and adds their links to create the level 2 transit network.

Step 3: Journey Optimizer finds shortest path between every pair of the visiting locations based on selected criteria (cost, time, distance) disutility, etc.

Step 4: Journey Optimizer finds the shortest sequence (next shortest sequence for each iteration) of the visiting locations (the source and sink nodes must be first and the last nodes of the sequence, respectively.)

Step 5: Journey Optimizer computes travel time for each visiting location and calculates the time needed for each travel.

Step 6: Journey Optimizer checks feasibility of the itineraries against the constraints given by the user.

No

Feasible?

Yes

Step 7: Journey Optimizer computes the itinerary attributes (total cost, total time, disutility, total distance, etc).

Step 8: System Output Manager presents the proposed itinerary (in graphic and text) and related attributes.

Figure 2- Flowchart of Rahyar Journey Optimizer
sen. At last, in Step 7, the itinerary details will be presented to the user both in graphic and text format. It should be mentioned that CPLEX software were used in Rahyar system to solve the shortest path problem.

3-4 System Output Manager

The output to the user consists of an itinerary proposed by the system. In addition to display of the proposed itinerary, the related attributes are also provided to the user upon request. Desired attributes include the followings.

* The sequence of the visits;
* Travel mode for each trip in the itinerary;
* Total disutility of the itinerary;
* Total travel distance associated with the itinerary;
* Total walking distance in the itinerary.

In addition, the following is desired if transit is taken.

* Bus Stop names and transfer locations;
* Number of transfers;
* Waiting time.

4. Journey optimization in Rahyar

In Rahyar, the Journey Optimizer component is responsible for itinerary planning. In this section, finding optimum itinerary (based on user inputs) is described. Journey planning is a sort of optimization problem. In this paper, the journey-planning problem is formulated as a Traveling Salesman Problem with Time Windows (TSPTW). In the following subsections, first, the TSPTW mathematical formulation is described. Then, a simple example is presented.

4-1 Traveling Salesman Problem with Time Windows

The TSPTW involves finding the minimum cost tour in which all cities are visited once within their requested time windows (Savelsbergh, 1985). This problem has a number of important practical applications including scheduling and routing.

The distances between n cities are stored in a distance matrix $D$ with elements $d_{ij}$, where $i, j = 1, 2, ..., n$ and the diagonal elements $d_{ii}$ are zero (Hahsler & Hornik, 2007). In the 1920s, the mathematician and economist Menger publicized this problem among his colleagues in Vienna. In the 1930s, the problem reappeared in the mathematical circles of Princeton (Applegate et al., 1998). In the 1940s, mathematician Flood publicized the name TSP throughout the mathematical community (Lawler et al., 1985).

Despite this simple problem statement, solving the TSP is difficult, since it belongs to the class of NP-complete problems (Johnson & Papadimitriou, 1985). The importance of the TSP arises besides its theoretical appeal for a variety of applications. Typical applications in operations research include vehicle routing, computer wiring, cutting wallpaper, job sequencing and job scheduling. Developing the appropriate method is one of the important research areas (Hahsler & Hornik, 2007). The TSPTW can be formulated as follows.

Minimize $z(x) = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_{ij}$

subject to

$\sum_{i=1}^{n} x_{ij} = 1, \quad j = 1, ..., n,$

$\sum_{j=1}^{n} x_{ij} = 1, \quad i = 1, ..., n,$

$e_i \leq T_i \leq l_i, \quad i = 1, ..., n,$

$x_{ij} = 0 \text{ or } 1$ (5)

Let $T_i$ be a variable indicating the time in which the service at the node $i$ begins and $x_{ij}$ be a binary variable. For any solution $X = (x_{ij})_{n \times n}$, consider the set $S=\{(i, j) : x_{ij} = 1\}$. Clearly, $S$ represents a tour or a collection of sub tours in graph. Objective (1) minimizes the cost. Constraint (2) requires the traveler to leave each node once and constraint (3) requires the traveler to arrive at each node once. Constraint (4) ensures the schedule feasibility with respect to time windows. Binary conditions on the variables are expressed by the last constraint (5).

In order to model the TSPTW as an integer program, the additional restrictions must be included to make sure that $S$ does not contain any sub tours. These restrictions are called sub-tour elimination constraints.

Miller et al. (1960) showed that by using $(n - 1)^2$ additional constraints and $(n - 1)$ additional variables, it is possible to ensure that $S$ is free of sub tours. These constraints are given by

$$(n-1)x_{ij} + u_i - u_j \leq (n-2), \quad i, j = 2, 3, ..., n,$$ (6)

where $u_i, (i=2, 3, ..., n)$ are unrestricted real variables.

If $S$ contains any subtour (a cycle with less than $n$ arcs), then $S$ will contain a subtour $T$ that does not contain node
1. If T is a single node, say \( \{k\} \), then inequality (6) is violated, if \( i = j = k \). If T contains more than one node, then adding the above inequalities for arcs in T leads to a contradiction (Gutin & Punnen, 2002).

4-2 A Simple Example

In order to describe the presented mathematical model, a simple example is considered. The multimodal network illustrated in figure 3 is assumed. In this network, three service lines (Subway, BRT-Line 1 & BRT-Line 2) represent multimodal network in which related icons are used to show the service line stations. Adjacent stations (which are just near each other) are also represented by adjacent icons. A number is assigned to every station, and the assumed network has 21 stations. Gray squares (O, D1, D2, and D3) are the origin and destinations. The aim is to find the best sequence of trips and modes from O to the destinations and get back to O as the trip sink, taking into account minimum disutility, traveler preferences and constraints such as time windows.

In this case, the spatial data of each station is gathered in advanced and the distance between each pair of stations is computed based on actual distance. In this stage, network level 1 is created. User selects the source (O) and destination of trips and actual distance between each locations and stations is calculated to make level-two network. As described in table 1, the traveler indicates preferences and constraints. Then, user preferences are used to compute mode disutility index (7), where \( n \) is the number of trip attributes, \( a_i \) is trip attribute and \( b_i \) is trip attribute related to weight. This index tells Rahyar the user ranking with regard to use of each transportation mode and is used to compute the disutility matrix (8).

As described before, the next step is to find the tour with minimum disutility.

\[
\text{Mode disutility index} = \sum_{i=1}^{n} a_i b_i 
\]

(7)

\[
\text{Disutility Matrix} = (\text{Distance matrix}) \cdot \text{(Mode disutility index Matrix)} 
\]

(8)

![Figure 3- An example of multimodal network](image)

Table 1-Sample User preferences of trip attributes(Considered by a user)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Trip Attributes(a)</th>
<th>Mode Disutility index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Trip Discomfort</td>
<td>Trip Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subway</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>BRT</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Walking</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>(Attribute Weight (b</td>
<td>0.9</td>
</tr>
</tbody>
</table>
As illustrated in figure 4, the shortest path, or in other words, minimum disutility between each pairs of location is found.

In the next step, the Optimizer finds the best tour with regard to the disutility function. Based on the results, the best route sequence is 22, 24, 25, 23 and 22. It means that the traveler could start the trip with destination D2, and then go to D3, then go to D1 and finally get back to O (as trip Sink).

Therefore, the optimum route is (22-24-9-8-7-18-17-25-17-18-7-6-5-4-23-4-5-11-12-13-14-15-22). The proposed route is demonstrated on multimodal network in figure 5. Trip details and attributes are also presented in table 2. Rahyar is developed as web-based software. Therefore, the source of the itinerary could be anywhere in the city and the user can choose the source and sink of the itinerary anywhere in the city by clicking on the map.

In this paper, Greater Tehran is selected as the study area. Tehran with a daytime population of about 10 million and with a center area of over 2000 square kilometers, is the capital of the country, and is the hub of commercial, financial, cultural and educational activities in Iran. Rapid urban expansion over the past two decades in Tehran has resulted from a high population growth and increased rural-urban migration combined with a strong tradition of centralization in the country.
5. Case Study: Tehran BRT-Subway Network

Shares of different transport modes and their types in the traffic of Tehran are shown in table 3. As can be seen, the public transit (Bus and Subway) in recent years has a smaller share than planned, and this shortcoming persuades urban planners and managers to react in a more sustainable manner. It should be mentioned that the share of private vehicles traveling in the urban areas has been estimated at about 40 percent. Public transportation in Tehran employs six main modes: cab, van, mini bus, bus, BRT and subway.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of Subway</td>
<td>6</td>
<td>7</td>
<td>30</td>
<td>30</td>
<td>6 7.3</td>
</tr>
<tr>
<td>Share of Buses and Mini-Buses</td>
<td>19.6</td>
<td>19</td>
<td>25</td>
<td>25</td>
<td>21 21.5</td>
</tr>
<tr>
<td>Share of Cabs, Vans and Automobile Agencies</td>
<td>23.5</td>
<td>24</td>
<td>20</td>
<td>20</td>
<td>22 22</td>
</tr>
<tr>
<td>Share of all kinds of services</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>--</td>
<td>10 9</td>
</tr>
<tr>
<td>Total share of Public and Semi-Public transportation</td>
<td>59.1</td>
<td>60</td>
<td>75</td>
<td>75</td>
<td>59 59.8</td>
</tr>
</tbody>
</table>
Among these, subway and BRT, due to their high speed, are of the greatest interest to travelers and commuters. The proposed model and developed DSS is applied on Tehran transit network data by focusing on subway and BRT. Figure 6 illustrates the transportation network in Tehran. It should be mentioned that as the most of passenger transportation in Greater Tehran in public transport area is by BRT & subway and main purpose of DSS development was to persuade people to use public transportation fleet, only these two transport modes are considered in Rahyar. Furthermore, since BRT & subway have their specific routes and are not much affected by timing, and there were no comprehensive data to evaluate the time effect on routes, time factor was eliminated in Rahyar.

As shown in figure 7, the dataset which is the main body of geo-database, consists of pathways (i.e. streets, avenues, and highways used by BRT), subway system (consisting of lines and stations), and BRT stops. As indicated in figure 8, the traveler wants to depart from the Source node at 8:30 am, visiting locations D1, D2, D3 and D4 and finally return to the Source node. Among these locations, the traveler must visit location D2 between 9:30 and 11:00 AM and location D4 between 11:00 and 12:15. Furthermore, the traveler estimates that the visits on locations D1 to D4 might take 10, 25, 10 and 30 minutes, respectively. The traveler prefers to use public transit and thus selects Subway and BRT as desired modes. The traveler also wants Rahyar to propose an optimum itinerary based on minimum disutility and thus assigns ranking 5 and 7 importance level to time and discomfort criteria. Based on the above information, the proposed itinerary will be as illustrated in figure 9. Based on figure 9, the following different transportation sequences are computed by Rahyar. It should be mentioned that because of the size of problem (number of nodes, links, modes and etc.) software running time is too short and time is not a major consideration in Rahyar.

- **1st trip: From Source to D1**
The traveler has to go to Vanak Sq. bus station on foot, takes the BRT-Line 6 to Qeytaria bus station. Then, the traveler needs to go to Qeytaria Subway station on foot,
takes Subway-Line 1 to Haghani Subway station and next goes to D1 on foot. This trip includes three means of transportation (by walking, Subway and BRT-Line 6) and five sequences (walk, BRT, walk, Subway and walk).

- **2nd trip: From D1 to D2**
  The traveler has to go back to Haghani Subway station on foot, takes the Subway-Line 1 to Mosalla Subway station. Then, the traveler needs to go to Mosalla bus station on foot, takes the BRT-Line 7 to Jalal Bus station and next goes to D2 on foot. This trip includes three means of transportation (by walking, Subway and BRT-Line 7) and five sequences (walk, Subway, walk, BRT and walk).

- **3rd trip: From D2 to D4**
  The traveler has to go to Sadeqia Subway station on foot, takes the Subway-Line 2 to Mellat subway station. Then, the traveler needs to goes to D4 on foot. This trip includes two means of transportation (walking and Subway) and three sequences (walk, Subway and walk).

### Table 4- The proposed itinerary details and attributes.

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Mode</th>
<th>Disutility</th>
<th>Sub Routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Vanak Sq. Bus Station</td>
<td>Walking</td>
<td>10.94</td>
<td></td>
</tr>
<tr>
<td>Vanak Sq. Station</td>
<td>Qeytarie Bus Station</td>
<td>BRT-Line 6</td>
<td>1.80</td>
<td>From O to D1</td>
</tr>
<tr>
<td>Qeytarie Bus Station</td>
<td>Qeytarie Subway Station</td>
<td>Walking</td>
<td>1.73</td>
<td></td>
</tr>
<tr>
<td>Qeytarie Subway Station</td>
<td>Haghani Subway Station</td>
<td>Subway-Line 1</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Haghani Subway Station</td>
<td>D1</td>
<td>Walking</td>
<td>0.80</td>
<td>From D1 to D2</td>
</tr>
<tr>
<td>D1</td>
<td>Haghani Subway Station</td>
<td>Walking</td>
<td>2.49</td>
<td></td>
</tr>
<tr>
<td>Haghani Subway Station</td>
<td>Mosalla Subway Station</td>
<td>Subway-Line 1</td>
<td>0.80</td>
<td>From D1 to D2</td>
</tr>
<tr>
<td>Mosalla Subway Station</td>
<td>Mosalla Bus Station</td>
<td>Walking</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Mosalla Bus Station</td>
<td>Jalal Bus Station</td>
<td>BRT-Line 7</td>
<td>2.49</td>
<td></td>
</tr>
<tr>
<td>Jalal Bus Station</td>
<td>D2</td>
<td>Walking</td>
<td>0.80</td>
<td>From D2 to D4</td>
</tr>
<tr>
<td>D2</td>
<td>Sadeqia Subway Station</td>
<td>Walking</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Sadeqia Subway Station</td>
<td>Mellat Subway Station</td>
<td>Subway-Line 2</td>
<td>1.17</td>
<td>From D2 to D4</td>
</tr>
<tr>
<td>Mellat Subway Station</td>
<td>D4</td>
<td>Walking</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>D4</td>
<td>Mellat Subway Station</td>
<td>Walking</td>
<td>1.61</td>
<td>From D4 to D3</td>
</tr>
<tr>
<td>Mellat Subway Station</td>
<td>Golbarg Subway Station</td>
<td>Subway-Line 2</td>
<td>1.61</td>
<td></td>
</tr>
<tr>
<td>Golbarg Subway Station</td>
<td>D3</td>
<td>Walking</td>
<td>1.02</td>
<td>From D4 to D3</td>
</tr>
<tr>
<td>D3</td>
<td>Golbarg Subway Station</td>
<td>Walking</td>
<td>0.80</td>
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</tr>
<tr>
<td>Golbarg Subway Station</td>
<td>Sarsabaz Subway Station</td>
<td>Subway-Line 2</td>
<td>2.34</td>
<td>From D3 to O</td>
</tr>
<tr>
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<td>Sarsabaz Bus Station</td>
<td>Walking</td>
<td>2.34</td>
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</tr>
<tr>
<td>Sarsabaz Bus Station</td>
<td>Gisha Bus Station</td>
<td>BRT-Line 5</td>
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<td>2.05</td>
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<tr>
<td>Gisha Bus Station</td>
<td>Vanak Sq. Station</td>
<td>BRT-Line 4</td>
<td>1.61</td>
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</tr>
<tr>
<td>Vanak Sq. Station</td>
<td>Sink</td>
<td>Walking</td>
<td>0.60</td>
<td></td>
</tr>
</tbody>
</table>

| Total disutility | 42.91 |
| Number of Modal Changes | 9 |
| Total Distance (km) | 24.56 |
• **4th trip: From D4 to D3**
The traveler has to go to Mellat Subway station on foot, takes the Subway-Line 2 to Golbarg Subway station. Then, the traveler goes to D3 on foot. This trip includes two means of transportation (walking and Subway) and three sequences (walk, Subway and walk).

• **5th trip: From D3 to Sink**
The traveler has to go to Golbarg Subway station on foot, takes the subway-Line 2 to Sarsabz Subway station. Then, the traveler needs to go to Sarsabz bus station on foot and takes BRT-Line 5 to Gisha Bus station. The traveler again must go to another Gisha Bus Station on foot, takes the BRT-Line 4 to Vanak Sq. station. Finally, the traveler has to go to Sink on foot. This trip includes three means of transportation (walking, BRT - either Line 4 or Line 5 and Subway) and seven sequences (walk, Subway, walk, BRT Line 5, walk, BRT Line 4 and walk). Table 4 summarizes the above trip details.

### 6. Conclusions

The itinerary planner proposed in this paper, called Rahyar, is among the first travel planning tools that incorporates multiple destinations, multiple criteria, multiple constraints, and multiple modes of travel and time windows. It is also one of the first travel planners that brings the user into the itinerary development process and adjusts the objective function used to evaluate alternative itinerary such that the user’s preferences can be best reflected in selecting an itinerary. The development of Rahyar, thus, represents an ambitious effort to incorporate many features into one software package for travel planning.

It is believed that Rahyar is an effective tool that can help travelers to organize their itineraries in an efficient manner while observing many constraints that may exist. It is expected that Rahyar will provide not only personal benefit to the user, but also social benefits through increased public transit use and reduced traffic congestion.

### References


A Multimodal Trip Planning System Incorporating the Park-and-Ride Mode and Real-time Traffic/Transit Information, ITS World Congress, Busan Korea.


