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MULTIOBJECTIVE MODEL FOR DESIGNING CUSTOMIZED TOURIST TOURS

Abstract

The tourist sector has undergone many changes in recent years due to technological progress and demographic change. On the one hand, there have been immense advances in communication technology and easy access to the Internet, which have led to the globalization of tourist information and greater numbers of tourists being able to access information on a huge number of products. On the other hand, a substantial change has taken place in tourist preferences and behaviour, with a move away from standard trips to other more personalized options, where customer preferences are taken into account. They are not only looking for sun and beach activities, but are also interested in culture and heritage, thus distributing their time between cultural visits and relaxation and leisure. When planning a tour, the tourist's objectives may be in conflict because, among other factors, the most important attractions are usually the most expensive, and thus the tourist is clearly faced with a multiobjective problem. We develop a model to solve this problem, taking into account the diverse economic costs (transport, the cost of different activities, lodging, etc), the timing of the different activities, and his/her particular preferences.

Keywords

Tourism, tourist tours planning, multi-criteria selection of tourist tours packages.

Introduction

The tourist sector of the economy has experienced immense growth and various changes in recent decades, including a substantial transformation in tourist preferences and behaviour that has had several consequences.

We specifically focus on the fact that planning a trip has become a complex task because tourists are increasingly more demanding and require customized trips instead of standardized ones ([15], [11]). Several factors are involved in this issue.

First, tourist interests have evolved from traditional activities, such as sun and sand, to new ones, such as business tourism, cultural tourism, leisure and entertainment tourism, rural tourism, health tourism and religious tourism [5]. Thus, instead of having one main interest, there are large numbers of tourists who have several, and thus have to divide their time among different activities, which complicates planning the trip.

Second, changes in patterns of tourist behaviour affect trip planning. On the one hand, there are increases in short vacations, with tourists travelling on weekends and holidays, instead of during the summer vacation, such that he/she needs a personalized plan that fits his/her needs. Furthermore, tourists tend to book at the last moment, so they have little time for planning.

Third, another factor that influences these difficulties is the multitude of alternatives available regarding each element of a journey. This information is accessible to tourists, given the new technologies, and they can compare prices, features, etc. Searching and studying all this information involves a high time-cost, and he/she also has to coordinate and schedule these activities. These new tourist activities have arisen in recent years in the attempt to meet the needs of diverse types of tourists ([11], [25], [27]). Among such offers, we can highlight accommodation, catering, transport, additional activities (cultural, leisure parks, etc) or tourist intermediaries, and each of these groups provide various options to satisfy different types of tourists.

As noted, new technologies make planning a customized trip easier. First, they offer easy access to a large amount of tourist information, provided by suppliers and users, thereby facilitating tourist information searches. The tourist can obtain detailed information on tourist destinations, the activities in those destinations, updated tariffs, timetables, etc. The new technologies also provide various tools that assist the tourist during the Web-based purchasing process such that he/she can make the booking.

However, with so much information available, it is too complex for the tourist to study all the possible alternatives. In addition, studying and searching for the best alternative would not guarantee choosing the best option, since his/her objectives may be in conflict [18]. On the one hand he/she may wish to minimize costs, but on the other hand, he/she may wish to maximize the utility provided by the activities.

Thus, we consider that tourists require assistance in decision-making regarding the various alternatives when planning a trip. This is an opportunity to improve the sector, and is addressed by the development and implementation of a tool to facilitate the organization of a customized trip. This system would benefit both the tourist, because he/she would obtain the trip best suited to his/her needs, and also the travel agents, as it would enable them to offer added value to tourists, thus motivating the present work.

The aim of this paper, therefore, was to develop a model that would help the tourist to plan his/her trip, by helping him/her to choose the best alternative. We provide a detailed itinerary that includes all the activities at each time during the trip, by considering the tourist's wishes and any conflicts between his/her objectives. We also take into account the various constraints – such as the time available for the activities, the duration of each activity, the time spent on route from one activity to another and the budget, among others – in order to choose the most appropriate tourist route.

Various systems have been described in the literature, which have attempted to help tourists plan a customized trip; however, they have certain limitations, as they do not take into consideration all the elements needed to offer each tourist the most appropriate option. Thus, the present paper proposes a new system that takes into account these gaps.

Some support systems developed for the tourism sector have only attempted to facilitate the search for tourist information [4]. Other systems, when providing information, consider the tourism offer at that time [12]. Several systems provide recommendations regarding the destination or activities ([10], [21], [22], [3], [2], [24]).

Other systems take tourist location into account by means of global positioning systems, to indicate which activities are nearer and guide him/her towards a specific tour, whereas other systems also consider user profile [26]. Yet others consider the tourist's context ([28], [17], [23]), whereas some systems consider all these items at the same time ([19], [20], [13], [14]). Finally, some systems use multi-criteria techniques to consider the various issues that may arise when planning a trip ([7], [8], [9]).

As mentioned, this study attempts to meet the requirements and drawbacks of the systems and methods analyzed, to offer tourists a system that actually helps them choose the best alternative when planning a trip, and engaging in a series of activities during their stay. This system is so generic that it can be used for any tourist and can be applied to specific segments by incorporating a suitable database.

1. Model formulation

We formulate a model that can be applied to any tourist who wants to spend a certain number of days, *N*, in a specific area doing some activities (there are a number of possible activities, *M*). Thus, we help him/her to make a decision among various alternative tours.

Activities are classified into 3 groups – accommodation, restaurants, and visits – which are denoted by A_1, A_2 and A_3; the latter group includes museums, monuments, beaches, leisure, walks and other visits.

The set of alternatives is formed by the different itineraries that the tourist can follow. Each itinerary is composed of different tourist routes to be followed each day; by "tourist route" we mean an ordered set of activities that the tourist will do during the day. This set of activities is formed by the decision variables x_{ijt} ($i, j = 1, 2,\ldots, M; t = 1, 2,\ldots, T$), which are binary variables that take value 1 if the tourist moves from activity *i* to activity *j* on day *t*, and value 0 otherwise:

$$x_{ijt} = \begin{cases} 1 \ \textit{if tourist moves from activ. } i \textit{ to activ. } j \textit{ on day } t \\ 0 \ \textit{ otherwise} \end{cases} \qquad (1)$$

$$i, j = 1,....M; \quad t = 1,.....N$$

We also define some auxiliary variables to simplify the model: we denote by y_{jt} the number of times the tourist does activity *j* during day *t*, that is:

$$y_{\mathrm{jt}} = \sum_{i=1}^{M} x_{ijt} \ \ t = 1,.....N \qquad (2)$$

and we denote by y_j the number of times the tourist does activity *j* during the entire tour.

$$\mathrm{y}_{\mathrm{j}} = \sum_{t=1}^{N} y_{jt} \qquad j = 1,....M \qquad (3)$$

1.1. Objectives and constraints

We now define the tourist objectives and the constraints that the model must fulfil:

Objectives:

Regarding the objectives, we take into account: minimizing the cost of transport from one activity to another, minimizing the cost of the activities, maximizing the utility of the activities for the tourist, and adjusting the time dedicated to each type of visit to the preferences of the tourist.

- First, we minimize the cost of transport from one activity to another. This cost depends on the distance between the place of activity and the means of transport; we assume the tourist travels by car. Thus, this objective is equivalent to minimizing the distance measured in kilometres during the tour, and is formulated as follows:

$$Min \sum_{i=1}^{M} \sum_{i=1}^{M} \sum_{t=1}^{N} d_{ij} x_{ijt} \quad (4)$$

  where d_{ij} represents the distance from activity i to activity j.

- The second objective is to minimize the cost of the activities. The formuation for this objective is:

$$Min \sum_{j=1}^{M} \sum_{t=1}^{N} c_j y_{jt} \quad (5)$$

  where c_j is the cost of activity j. This cost can be broken down as follows: accommodation cost, restaurant cost, and visit cost, and could be equal to zero in the case of free activities, e.g., visiting a park or going to the beach.

- The third objective is to maximize tourist satisfaction with the activities, which is calculated by aggregating the relevance of the activity and the tourist's preferences. The formulation for this objective is as follows:

$$Max \sum_{j=1}^{M} \sum_{t=1}^{N} u_j y_{jt} \quad (6)$$

  where u_j is the utility of activity j. Relevance is measured by the importance of the activity in the media, quality, etc. Regarding tourist preferences, and given the tourist does not have complete information, we assume that the tourist places a value on some characteristic of the activity. For example, each activity can be classified into subtypes; museums can be art museums, history museums, etc.

– The final objective is to adjust the time dedicated to each type of visit to the preferences of the tourist. We minimize the distance between "Real Time of Visit" and "Desired Time of Visit". The formulation for this objective is:

$$Min \quad \left| ttar_{3k} - ttad_{3k} \right| \qquad k = \{1,...w\} \tag{7}$$

where we denote by $ttar_{3k}$ an auxiliary variable that indicates the real time dedicated to the type of visit k and denote by $ttad_{3k}$ an auxiliary variable that indicates the time the tourist wishes to dedicate to the type of visit k. We define these variables as follows:

Real Time of Visit:

$$ttar_{3k} = \sum_{j \in A_{3k}} \sum_{t=1}^{N} ta_j y_{jt}, \quad k = \{1,...w\}, \quad j = \{1,...M\} \tag{8}$$

where ta_j is the duration of activity j. The duration of activities depends on the average duration of the activity, the decision-maker's preferences, and a rest period.

Desired Time of Visit:

$$ttad_{3k} = pd_{3k}\ Tv \qquad k = \{1,...w\} \tag{9}$$

where pd_{3k} is the percentage of the total time dedicated to visits that the tourist wishes to dedicate to the type of visit k; and Tv is the total time dedicated to visits during the tour. This is defined as:

$$Tv = \sum_{j \in A_3} ta_j y_j \tag{10}$$

Once the objectives have been determined, we formulate the constraints of the model.

There are two types of constraints: permanent constraints, which are independent of the decision-maker, that is, they must be fulfilled anyway; and the decision-maker's constraints, that is, when the tourist wishes the tour to have certain characteristics.

Permanent constraints:

– If a tourist does activity j ($j = 1, 2,\ldots, M$) on day t ($t = 1, 2,\ldots, T$), the tourist must finish activity j during day t, unless activity j is accommodation, in which case the tourist will stop activity j the following day.

$$\sum_{i=1}^{M} x_{ijt} = \sum_{k=1}^{M} x_{jkt} \qquad \forall j \begin{cases} \notin A_1 \\ \neq initial \;\; point \;\; , \quad t = 1,\ldots N \\ \neq end \;\; point \end{cases} \tag{11}$$

– Regarding accommodation, the tourist will leave the day after arrival, and therefore:

$$\sum_{i=1}^{M} x_{ijt} = \sum_{k=1}^{M} x_{jk,t+1} \quad \forall j \in A_1 \quad t = 1,\ldots N-1 \tag{12}$$

This constraint does not affect to the last day of the tour, because the tourist arrives to the accommodation, but he/she does not leave for any other activity. In this case, accommodation will be the end point.

– On the first day, the tourist starts from an initial point indicated by him/her (airport, train station, accommodation from a previous stage, etc). From this point, he/she leaves for a given activity, but does not have to return, so we must add the following constraint:

$$\sum_{j=1}^{M} x_{ijt} = 1 \quad i = initial \;\; point\,, \;\; t = 1 \tag{13}$$

– Likewise, an endpoint is a point of arrival but not a point of departure, therefore it does not fulfil the previous constraints and we must add the next constraint:

$$\sum_{i=1}^{M} x_{ijt} = 1 \quad j = end \;\; point\,, \;\; t = N \tag{14}$$

– The tourist must seek accommodation each day when a route with an over-night stay is planned. Accommodation is selected in a previous stage (as described below) based on tourist satisfaction:

$$y_{jt} = 1 \qquad \forall j \; set \;\; accommodation \;\; for \, day \;\; t \tag{15}$$

– The maximum number of times that the tourist can do an activity during the entire tour is indicated by "*Numrepetitions*". This number depends on each type of activity, e.g., a church will be visited only once:

$$\sum_{t=1}^{N} y_{jt} \leq Num\, repetitions_j\,, \quad j = 1,\ldots M \tag{16}$$

– Regarding restaurants, different circumstances can occur: depending on the tour timetable, we may plan one, two or no meals in a day, but, if possible, a meal will be planned:

$$\sum_{j\in A_2} y_{jt} = 2 \qquad t \in D_{ac}\,;\, D_{ac} = \{t : I_t 13:00 \ y\ F_t 22:00\} \qquad (17)$$

$$\sum_{j\in A_2} y_{jt} = 1 \qquad t \in D_a\,;\ D_a = \{t : I_t 13:00 \ y\, 15:00 \le F_t 20:00\} \qquad (18)$$

$$\sum_{j\in A_2} y_{jt} = 1 \qquad t \in D_c\,;\ D_c = \{t : I_t 15:00 \ y\ F_t 22:00\} \qquad (19)$$

$$\sum_{j\in A_2} y_{jt} = 0 \qquad t \in D_s\,;\ D_s = \begin{Bmatrix} t : I_t \ge 15:00 \ y \ F_t \le 21:00, \\ ó \ \ F_t \le 13:00 \end{Bmatrix} \qquad (20)$$

D_{ac} being the days when it is possible to plan both lunch and dinner; D_a, the days when it is possible to plan only lunch; D_c, the days when it is possible to plan only dinner; and D_s, the days when it is not possible to plan any meal. We denote by I_t the time when the tourist wants to start the route on day *t*, and by F_t, the time he/she wants to finish, defined as the time of arrival at the accommodation.

Each activity has a timetable, and the tourist must follow this schedule. We define auxiliary variables, HI_{jt}, as the starting time of activity j ($j = 1, 2,\ldots, M$) on day t ($t = 1, 2,\ldots, T$), and HF_{jt} as the finishing time of this activity.

– The finishing time of an activity is equal to the starting time of this activity plus its duration; it occurs if this activity is done, if not it is equal to zero, the constraint being as follows:

$$\mathrm{HF_{jt}} = \mathrm{HI_{jt}} + ta_j\, y_{jt}\ , \qquad \begin{cases} j \notin A_1 \\ j \ne \text{initial point} \end{cases} \qquad t = 1,.....N \qquad (21)$$

ta_j being the duration of the activity *j*. We use the variable y_{jt}, defined in expression (2) as the number of times that activity *j* is done on day *t*:

$$\mathrm{HF_{jt}} = \mathrm{HI_{jt}}\, , \qquad \begin{cases} j \notin A_1 \\ j \ne \text{initial point} \end{cases} \qquad t = 1,.....N \qquad (22)$$

in expression (30), $HI_{jt} = 0$ for activities not carried out.

This is true for any activity except for accommodation and the initial point. In the case of accommodation, we define the start time and the end time according to the preferences of the tourist. In the case of the initial point, the tourist has not arrived at this point from another activity, so it is considered by expression (3) as an activity not carried out, and the start time will be equal to zero by expression (30). In such cases we cannot add this constraint, and introduce the following.

– If the tourist has indicated the initial point, the start time of the tour is defined by him/her, or we assume that the start time is the first day, accommodation being the initial point. The start time is defined as the finish time of the initial point:

$$HF_{jt} = star\ time\ tour\ , \qquad j = initial\ \ point \qquad t = 1 \tag{23}$$

– The finish time of the tour is the start time of the end point, and is indicated by the tourist, or we assume the finish time of the last day:

$$HI_{jt} = end\ time\ \ tour\ , \qquad j = end\ \ point \qquad t = N \tag{24}$$

– The start and the end times of accommodation are indicated by the tourist. He/she can indicate at what time he/she wants to start each day, I_t, and at what time he/she wants to finish, F_t; and if the tourist does not indicate either of these, we assign values 9:00 and 21:00.

  – The start time of the route on day t is equal to the finish time of accommodation, except on the first day because he/she does not end accommodation.

$$HF_{jt} = I_t\, y_{jt} \quad j = set\ accommodation,\ t = 2,.....N \tag{25}$$

  – The time when the tourist wants to finish the route on day t will be the start time of accommodation on day t.

$$HI_{jt} = F_t\, y_{jt} \quad j = set\ accommodation,\ t = 1,.....N \tag{26}$$

– The start time of activity j ($j=1,\ldots M$) on day t ($t=1,\ldots N$) should be greater than or equal to the time of finishing the previous activity i, ($i=1,\ldots M$), plus travel time from i to j.

$$\mathrm{HI}_{jt} \geq \mathrm{HF}_{it} + td_{ij} - 1000000 \quad (1 - x_{ijt}) \qquad i, j = 1,...M \quad t = 1,.....N \tag{27}$$

where td_{ij} is the spent time going from activity i to activity j.

If the tourist does not go from activity i to activity j, this constraint will not affect the model, so we have incorporated the variable x_{ijt} in constraint (27).

– The start time of activity j should be greater than or equal to the opening time of this activity, e_{jt} being the opening time of activity j on day t:

$$HI_{jt} \geq e_{jt} y_{jt} \qquad j \notin A_1 \qquad t = 1,\ldots. N \tag{28}$$

– The start time of activity j should be less than or equal to the "last visit time" of the activity j on day t:

$$HI_{jt} \leq l_{jt} y_{jt} \qquad j \notin A_1 \qquad t = 1,\ldots. N \tag{29}$$

where l_{jt} is the "last visit time" of activity j, that is, the difference between the closing time (c_{jt}) and the duration of the activity, $l_{jt} = c_{jt} - ta_j$.

Tourist constraints:

Each tourist has preferences regarding the duration of the tour, free time, type of accommodation, type of visits, etc.

– The tourist may determine if he/she wants some free days:

$$\sum_{j=1}^{M} y_{jt} = 0, \quad t = set\ day\ by\ tourist \tag{30}$$

– The tourist may want to specify some activities, and the system will be forced to offer these activities.

$$\sum_{t=1}^{T} y_{jt} \geq 1, \quad j = set\ activity\ by\ tourist \tag{31}$$

– He/she may also specify what activities he/she does not want to do:

$$\sum_{t=1}^{T} y_{jt} = 0, \ j = set\ activity\ by\ tourist\ to\ not\ do \tag{32}$$

– And he/she may indicate what activities are his/her favourites:

$$u_j = Max\ value\ utility, \ j = set\ activity\ by\ tourist \tag{33}$$

"$Max\ value\ utility$" being the maximum value of any activity according to its characteristics and tourist preferences.

– The tourist may specify some types of visits that he/she prefers, and the system will be prevented from offering other types of visits.

$$y_j = 0, \forall j \in A_{3k} \quad k = unwanted\ type \ \ k = \{1,\ldots w\}, t = 1,\ldots N \tag{34}$$

– Regarding accommodation, he/she may indicate the following: locations where he/she wishes to stay, type of accommodation, accommodation category, minimum category, and minimum services.

– The tourist may indicate preferences regarding restaurants: type of restaurant, category, and type of cuisine.

– Regarding museums, monuments and other visits, the tourist may indicate what subtype he/she wishes to visit.

– The tourist may indicate preferences regarding beaches: composition, type of sand, bathing conditions, level of urbanization, average width, average length, density of use, minimum services and other characteristics.

– We also consider the maximum time on the route that the tourist wants to spend going from one activity to another, and this is denoted by the parameter "*tdMax*":

$$td_{ij}\, x_{ijt} \leq tdMax,\ \ j = 1,...,M;\ \ i = 1,...,M,\ \ t = 1,...N \tag{35}$$

If the tourist does not indicate this amount of time, we assume *tdMax* = 4 hours.

– The tourist may indicate whether he/she prefers a relaxed tour, with a rest period (approximately 10% of the duration of activity) between one activity and another, or whether he/she prefers to do as many activities as possible.

$$ta_j = tar_j + m\, tar_j\,,\ \ j = 1,...,M;\ \ i = 1,...,M,\ \ t = 1,...N \tag{36}$$

"*m*" being the percentage used.

2. Model resolution

We studied the model and concluded that it corresponds to a Multi-objective Assignment and Routing Problem. It is an assignment problem as the tourists must choose which activities to do each day from among all the activities on offer, that is, they have to assign activities to days; it is a routing problem as these activities have to be ordered for each day; and it is a multiobjective problem since, among other difficulties, it involves choosing a satisfactory alternative from among the multiple objectives of the decision-maker ([1], [16]).

The complex character of the problem makes it very difficult to solve using exact methods, and therefore we chose other methods, known as metaheuristics. We used a metaheuristic method based on Tabu Search. This search method itself is based on the concept of memory taken from the field of Artificial Intelligence. By means of this procedure, and once all the information required from the decision-maker has been collected, an approximation to the set of efficient solutions is obtained [6].

This procedure provides a very large set of alternatives, and therefore an interactive and iterative process is required that gradually reduces the set of solutions obtained, using the information provided by the decision maker. This guides the search for an efficient frontier area where the most suitable solution will be found, yielding a set of solutions tailored to tourist preferences.

Conclusions

In a world where tourist information is widespread and readily available, each tourist may plan his/her own trip. However, this involves an important cost in terms of effort and time, due to the wide range of tourist products in the market and to conflict among the objectives of the tourist.

Therefore, a system is required which facilitates the tourist's decision-making process, and which also offers him/her the alternative best suited to his/her needs.

We have met this need by creating a tourist aid system, which could act as an efficient tool within the tourist sector, that is, for the tourist, travel agencies or official bodies. The system facilitates the tourist's decision-making process; and travel agencies and official institutions can use this system to offer an additional service to the tourist. Similarly, this work may serve as a methodological tool in other areas of interest.

Future lines of work include developing an interactive method to guide the decision-maker in finding an appropriate solution, as mentioned; developing a computer implementation that incorporates the various stages of the process and, by means of an interface, also collects the information needed from the decision-maker and shows him/her the solutions; and fine-tuning the model to match reality as far as possible.

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