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Challenges in Real World Sightseeing Tour Optimization Using Meta-Heuristics

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Abstract: The objective of the present research consists in applying combinatorial optimization to real world trip planning. Multiple objective combinatorial optimization problems are suggested that model different situations with regards to the planning of trips. Solving these problems, e.g. with meta-heuristics, makes it possible to provide the user with decision support in this matter. It will be focused on the case of sightseeing tours, for which a whole area is visited, from and back to a specified point of origin/destination, with accommodation in hotels and transportation by car or chartered bus.

Key-Words: Multiple Objective Combinatorial Optimization (MOCO), Tourism, Trip Planning, Sightseeing Tours, Meta-Heuristics, Simulated Annealing, Tabu Search.

1 Introduction

Operations research has already been used in most fields of the human activity. Though, applications of operations research in tourism are not very usual, despite the major importance of tourism for the world economy and for individuals. For example, the application of operations research to trip planning has hardly been studied. Trip planning can be defined as "selecting and combining, in a trip, the most appropriate tourism products (lodging, transportation...) considering a tourist's personal values, wishes and constraints".

Given the difficulty of choosing among the countless tourism components which are available, and combining them in a consistent way, trip planning can turn out to be similar to a Chinese puzzle. Moreover, the planning activity requires a great deal of technical skill, for example to work out prices. Yet, vacation choices are high-involvement decisions and represent a considerable proportion of the household budget [6][7]. As a result, tourists will usually devote appreciable time and effort to the selection of the "ideal" trip. Trip planning plays an important part in the success of a trip, and even though it is not easy for the customer to take part in that enterprise, it is thus often in his interest to do so.

Over the last ten years, a substantial shift occurred in the behaviour of tourism consumers, away from standardized packages of tour operators to individualized products [1]. This change leads to a higher involvement of the tourist directly in the planning process. As a result, a great many tourism companies have offered new possibilities to assist and sometimes encourage the tourist in this activity : "hotel only" brochures and bookings, toll-free access to reservation desks, etc. The Internet and other networks have grown up in this context and made a handsome contribution to it by enabling the general public to access professional reservations systems and thus directly make their own reservations online.

Although tourists can already book many travel components online, only little has been done so far with regard to the trip planning process as a whole. Many web sites enable users to choose and book flights, hotels or rental cars but do not give much assistance when it comes to putting together those services.

Since trip planning consists in selecting and combining tourism products, with several constraints and objectives, the tools of combinatorial optimization seem to be very appropriate for modeling in this matter. As a matter of fact, combinatorial optimization is the branch of operations research that deals with the problems of finding the best (or one of the best) element(s), according to a given objective function, in a finite non-empty set, of which the elements usually consist in combinatorial "assemblages" (e.g. permutations) of simpler items. The selection and combination process underlying trip planning can be seen as the problem of choosing among numerous combinatorial assemblages (of travel products).

The objective of the present research consists in applying combinatorial optimization to real world trip planning. Combinatorial optimization problems are suggested that model different situations with regards to the planning of trips. Solving these problems, e.g. with meta-heuristics, makes it possible to provide the user with decision support in this matter. It will be focused on the case of sightseeing tours, for which a whole area is visited, from and back to a specified point of origin/destination, with accommodation in hotels and transportation by car or chartered bus.

2 The Trip Planning Problem

A very central and famous combinatorial optimization problem is the traveling salesman problem (TSP), which simply stated consists in finding one of the best (cheapest) orders for a salesman to visit a set of places, before coming back to his starting point. Since trip planning is essentially a tour construction problem, the TSP seems to be useful in very basic trip planning situations, where a set of tourist attractions have to be visited, while minimizing transportation cost. Therefore, the TSP is a good starting point to model trip planning.

Yet, from a trip planning point of view, a first major drawback of the TSP is its inability to select activities to be included in the tour. A second inadequacy comes from the fact that the TSP does not deal with lodging at all. Accordingly, an initial alteration of the TSP consisted in enabling selection of activities (TSP-AS), lodging (TSP-LS) or both (TSP-ALS). In the TSP-ALS, activities have to be selected and lodging inserted so that the trip spans a given number of days, of which the active duration always fits between a lower bound and an upper bound. As for the TSP, the objective is to find a sequence (tour) with the minimum transportation cost.

Even though the solution structure of the TSP-ALS is now appropriate to represent trips, shortcomings remain regarding the objective of the problem. Indeed, in most trip planning situations, selection based on transportation cost only is not conceivable. Activity and accommodation costs should also be considered. Therefore, a new alteration gives rise to the multiple objective TSP-ALS (MOTSP-ALS), in which three separate objectives have to be taken into account at the same time : minimizing total transportation cost, minimizing total lodging cost, and minimizing total activity cost.

Finally, a last major improvement which is necessary to model trip planning consists in taking into consideration not only the components' costs but also the tourist's preferences. Beside minimizing the three costs, maximizing lodging and activity attractiveness leads to define a problem with five objectives : the preference-based MOTSP-ALS (PB-MOTSP-ALS), which was nicknamed "trip planning problem" (TPP).

This series of improvements and the extensions of the TSP to which they led, specifically for trip planning, are summarized in Figure 1.

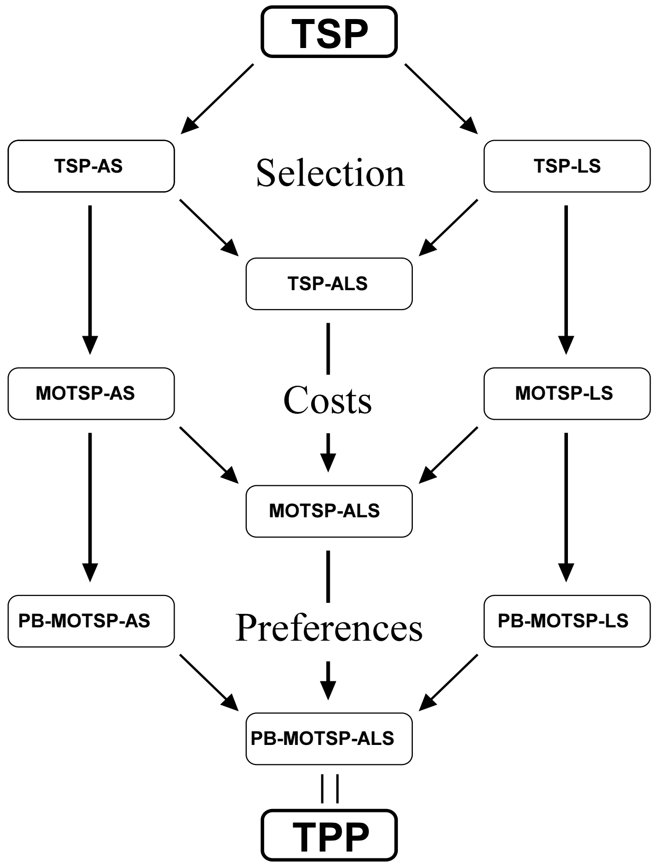

Fig. 1. Successive alterations of the TSP.

To keep it rather simple, the principle of the TPP is schematised in figure 2. Trips are built as sequences of different activities (attractions in the case of sightseeing tours) and of N, possibly redundant, lodgings that are selected from databases (N is the number of nights as imposed by the tourist). All these sequences start and finish at the same "point of origin and destination" (represented by a black square in figure 1), which is also chosen by the tourist. Knowing the duration of each activity and the time needed to go from a place (point of origin and destination, activity, or lodging), to another, it is ensured that the time elapsed between two consecutive lodgings in the sequence falls between d^- and d^+, which are respectively a lower and an upper bound on the active duration of every day of the trip.

Finally, knowing the cost and the attractiveness of each activity and lodging, and knowing the cost of going from a place to another, all the feasible trips (sequences) can be evaluated as to five conflicting objectives : "minimisation" of the cost of transportation, "minimisation" of the cost of activities, "minimisation" of the cost of lodgings, "maximisation" of the attractiveness of activities and "maximisation" of the attractiveness of lodgings. The TPP consists in selecting one (or a few) of the best compromises with regard to these objectives.

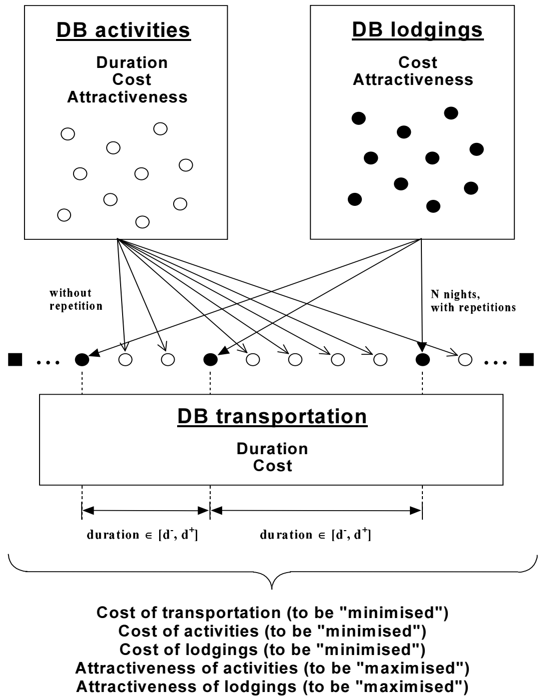

Fig. 2. Principle of the TPP

As an example, figure 3 gives the spatial representation of what could be a solution of the TPP [2][3][5].

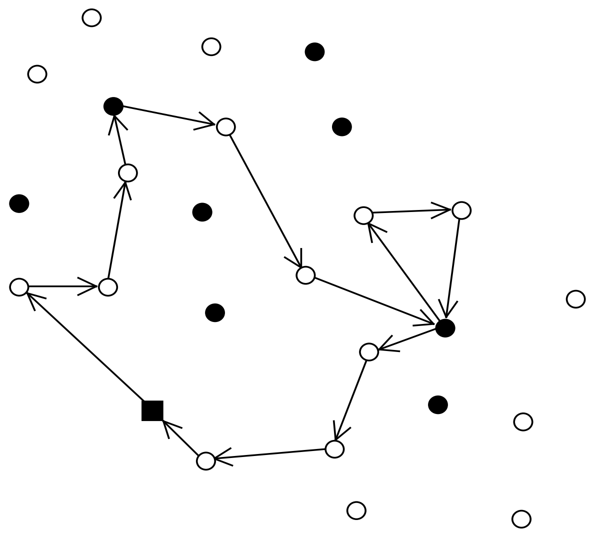

Fig. 3. Configuration of a TPP solution.

The TPP can play a very central part in trip planning, just like other extensions of the TSP do in various fields (e.g. the vehicle routing problem to plan delivery rounds). Because of the assumptions on which the TPP relies, this problem is especially appropriate as a basis for modeling sightseeing tour planning [3][4]. However, it can also be used as a starting point for trip planning at large.

3 Beyond the TPP

From a practical point of view, there are many ways in which the model based on the TPP can be improved, to be made even more appropriate to trip planning, and especially sightseeing tour planning. However, it has to be remembered that the problem underlying the model needs to be solved to find optimal or, at least, close-to-optimal solutions (trips). As a matter of fact, it has to be kept in mind that the TPP is already difficult to solve as a combinatorial optimisation problem and that computation times increase drastically as the instance size (number of activities, lodgings...) gets larger. Thus, it is important to make sure that good solutions for normal instances of the new problems can still be obtained in a reasonable amount of time.

Moreover, it also has to be taken into account that the data needed for the new model must be available. For data that needs to be input by the decision-maker, it is necessary to make sure that this can be done in real world situations, for example on a B-to-C web site.

At this stage, four main alterations of the TPP-based model have been considered reasonable and studied further [4]. They concern (1) the selection of the origin and the destination of the trip, (2) the inclusion of specific activities, (3) the inclusion of specific lodgings, and (4) the variability of time spent at attractions.

3.1 Selection of origin and destination

In the TPP, it is assumed that the trip starts and finishes at the same place, which is called "point of origin and destination" ; it is also supposed that the tourist knows what is the right point of origin and destination for her/his trip (e.g. Miami International Airport, for a trip in Florida).

In reality, a sightseeing tour is not always a tour as such, since the tourist can decide to start at a place (e.g. Miami International Airport) and finish at another place (e.g. Orlando International Airport). Moreover, in the first stage of the planning process, the tourist may have no idea of where her/his sightseeing tour should start and finish. Hence, it is desirable to set up an improved model where the "point of origin" and the "point of destination" need not be the same place, and where these points are selected endogenously (that is by the model itself) based on what seems to be most appropriate. Yet, it should still be possible for the tourist to decide on the point of origin and/or the point of destination, or require them to be identical.

To improve the TPP model in this respect, two extra databases were added to what was presented in figure 2 : one database of possible points of origin and one database of possible points of destination. The optimisation algorithm then needs to be modified as to select the point of origin and the point of destination of the trip from the respective database. Also, an optional constraint can oblige the algorithm to select the same place in both databases.

3.2 Inclusion of specific activities
Another implicit hypothesis of the TPP model considers that there is no activity that the tourist absolutely requires to be included in the trip. As a matter of fact, any activity of the database of activities can or cannot be selected, depending on what seems to be better, considering the trip as a whole.

Yet, most often the tourist knows as from an early stage in the planning process that an activity has to be part of her/his trip, because she/he considers that activity as a "must-do". For example, a tourist who is planning to go to Florida could consider that she/he absolutely has to go see "Disney World".

To take into account such requirements, the "must-do" activities have to be pinpointed in the database of activities. Furthermore, the algorithm needs to be modified as to include and keep those activities in the trip.

3.3 Inclusion of specific lodgings
The TPP model assumes as well that there is no lodging where the tourist absolutely wants to spend one night (or more) during her/his trip. In the same way as for activities, any lodging of the database of lodgings can or cannot be selected, depending on what seems to be better, considering the trip as a whole.

Again, though, the tourist can demand that one or several nights be spent at a given place. This can be due to a good past experience or to the reputation of the lodging in question. For example, a tourist who is planning to go to Florida could consider that she/he absolutely has to spend at least one night at the famous "Casa Marina" hotel, in Key West.

This kind of requirements can be dealt with by pinpointing the affected lodgings in the database of lodgings and by indicating the minimum number of nights that have to be spent there. The algorithm then needs to be modified as to include and keep in the trip the required number of copies of those lodgings.

3.4 Variability of time spent at attractions
A pretty strong simplifying assumption of the TPP consists in considering that each attraction requires a given amount of time (e.g. 8 hours to visit Disneyland). Yet, an extension of the TPP can be proposed, where the time dedicated to each attraction on the tour would be determined within the model. This way, the total available time will be shared out among the attractions in the best possible way.

In order to provide the user with useful recommendations, some expert knowledge has to be formalised and input as about the time that should be spent at an attraction by a given tourist. It will be considered here that this information consists at least of a minimum time, a maximum time, and a relation between the time spent at the attraction and the resulting attractiveness of this attraction for the tourist. Of course, the latter relation is the key element to ensure that realistic results are obtained.

In the new underlying operations research problem, time spent at any attraction is a variable that has to be optimised, with a direct effect on the attractiveness of the tour. This extension of the TPP makes it possible to plan sightseeing tours where the time spent in the attractions is optimised, in order to help tourists make the best possible use of their travel time. As it relaxes a rather strong assumption of the TPP, it is a big step towards effective assistance in the trip planning process, and especially for the customisation of sightseeing tours.

4 Solving with Meta-Heuristics
Of course the TPP and their variants are no easy to solve problems, because of their computational complexity and their numerous objectives. Appropriate tools to solve them are the meta-heuristics since these are known to perform well for the TSP and offer a high flexibility that makes them easier to adapt to derived problems [8]. Besides, a lot of attention has been devoted to multiple objective combinatorial optimization (MOCO) problems in the last years and multiple objective versions of meta-heuristics (e.g. the MOSA method) give promising results to determine quasi-efficient solutions of large-size MOCO problems [9][10].

As an example, using basic databases of 173 activities, 91 lodgings, and 3 origins/destinations (international airports), a 10-day sightseeing tour was planned in Florida for a fictitious couple of tourists.

This couple is supposed to have the following specific requirements as to what their trip should be like : it does not matter from what airport their tour starts, but they want to end up at the same airport ; they want to visit Palm Beach and Cypress Gardens ; they want to spend two nights at the "University Inn". Finally, it was assumed that they dedicate 10 hours a day to visiting and travelling.

The first sightseeing tour that was obtained, in about 20 seconds, is represented in figure 4. Considering indicative travel times between the different places, exactly 10 hours each day are dedicated to visiting and travelling. Travel plans are as follows :

Origin : Miami International Airport
Activity : Cypress Gardens - 5 h. 14 - $ 55.90
Lodging : Le Parc Inn - $ 43.00
Activity : Ybor City - 0 h. 59 - $ 0.00
Activity : Busch Gardens - 8 h. 09 - $ 69.20
Lodging : Le Parc Inn - $ 43.00
Activity : Disney-MGM Studios - 8 h. 22 - $ 74.00
Lodging : Maingate Hotel - $ 55.00
Activity : Magic Kingdom - 9 h. 38 - $ 74.00
Lodging : Maingate Hotel - $ 55.00
Activity : EPCOT - 9 h. 13 - $ 74.00
Lodging : Admiral's Inn - $ 53.00
Activity : Universal Studios - 9 h. 15 - $ 74.00
Lodging : Plaza International Hotel - $ 69.00
Activity : Sea World - 9 h. 08 - $ 71.90
Lodging : Space Shuttle Inn - $ 52.00
Activity : Kennedy Space Center - 4 h. 37 - $ 14.00
Activity : Palm Beach - 2 h. 21 - $ 0.00
Lodging : University Inn - $ 49.00
Activity : Little Havana - 1 h. 07 - $ 0.00
Activity : Art Deco District - 1 h. 09 - $ 0.00
Activity : Bal Harbor Beach - 6 h. 05 - $ 0.00
Lodging : University Inn - $ 49.00
Activity : Villa Vizcaya - 2 h. 19 - $ 20.00
Activity : Everglades N.P. - 5 h. 58 - $ 6.00
Destination : Miami International Airport

This example shows how the algorithm respected the tourists' constraints and how it shared out the total available time among the attractions, based on their attractiveness and also on the interdependence between them within a given period of time (a day here).

Of course the first trip which is proposed is not meant to be booked as it is. The couple can review the different parameters and have other sightseeing tours generated. This way, interactively, a fully customised tour will be designed for the tourists.

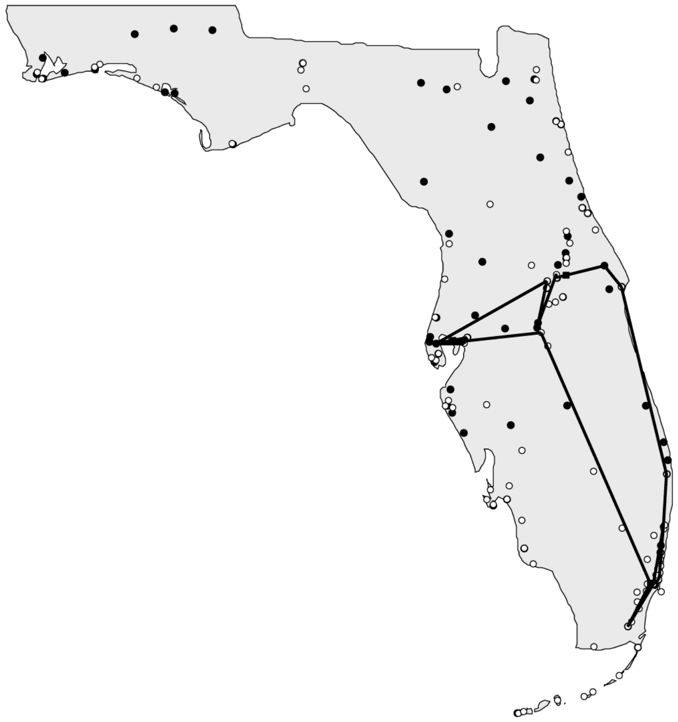

Fig. 4. Example of a sightseeing tour in Florida

5 Conclusion

The TPP appears as a good starting point to model sightseeing tour planning. Moreover, there are many ways in which the model based on the TPP can be improved, to be made even more appropriate to real world sightseeing tour optimization. However, it has to be remembered that the problem underlying the model needs to be solved to find optimal or, at least, close-to-optimal solutions (trips). As a matter of fact, it has to be kept in mind that the TPP is already difficult to solve. Thus, it is important to make sure that good solutions for normal instances of the new problems can still be obtained in a reasonable amount of time. Moreover, it also has to be taken into account that the data needed for the new model must be available.

These results brought to light that it is possible to design a decision support system (DSS) for real world sightseeing tour planning based on combinatorial optimization models, as for example the TPP. Such a DSS can be useful, in lots of different situations, to assist people in planning customized sightseeing tours : the independent traveler on the Internet, the travel agent making tailor-made arrangements, the tour operator packaging sightseeing tours, etc.

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