Applications of Operational Research Techniques in Optimization to Visit Tourist Points of Viña del Mar

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Chile is a country with great attractions for tourists in South America and the whole world. Among the many tourist Chilean attractions the city of Viña del Mar is one of the highlights, recognized nationally and internationally as one of the most beautiful places for summer. In Viña del Mar tourists have many options for leisure, besides pretty beaches, e.g. playa reñaca, the city has beautiful squares and castles, e.g. Castillo Wulff built more than 100 (one hundred) years ago. It is noteworthy that already exist over there five (5) tourist itineraries, so this work was developed in order to determine the best routes to these existing itineraries, and create a unique route that includes all the tourist points in Viña del Mar, because in this way, the tourists visiting this city can minimize the time spent in traveling, as well as optimize their moments of leisure, taking the opportunity to know all the city attractions. To determine shorter ways to do it and then propose some suggestions for improvement of the quality of the tourist service offered, it had used the exact method, by solving the mathematical model of the TSP (Traveling Salesman Problem), and the heuristic method, using the most economic insertion algorithm.

Keywords: *Tourism, Chile, Viña del Mar, Traveling Salesman Problem*

1 Introduction

The city of Viña del Mar, according to the web site http:://www.vinadelmar.cl, is considered the tourist capital of Chile. Viña del Mar is surrounded by several green areas, and also has thirteen (13) beaches for tourism and leisure, the temperature there along the year has mild summers and gentle winters. Due to its favorable climatic conditions, allied to their natural beauty and many options for leisure and tourist points, this city is one of the major Chilean tourism attractions nationally and internationally for people on vacation.

There are in this city, as shown on the site http://www.visitevinadelmar.cl, 5 (five) different tourism routes that visitors can visit city's main attractions and tourist points. These tourist routes are known as Ruta del Pelicano, Ruta del Cormorán, Ruta de la Gaviota, Ruta del Pinguino and Ruta del Albatros.

Considering all the tourism routes mentioned above, there is a total of 32 (thirty two) tourist points to be visited, including squares, castles, beaches and others. Occurs that Viña del Mar does not have buses that cover all those tourist points, in other words, it is necessary for the tourist to know which are the best options to visit each of the tourist points in the routes described above.

The objective of this work is to determine the best way to drive between the tourist points that pass each of the five (5) tourism routes described in this paper.

In addition, it will be developed a single route among all 32 (thirty two) tourist points of these 5 (five) tourism routes.

2 Review of the Literature

2.1 Linear Programming

Linear programming is according to [3], programming models where the variables are continuous and have a behavior said as linear to the objective function and the restrictions involved.

2.2 Integer Programming

Integer programming is, by [8], the name given to linear programming problems in which the variables can only assume integer values. A particular case of integer programming is when the variables can only assume dichotomous values, i.e. 0 or 1. In this case, the model is called zero-one programming or binary programming.

The creation of the integer programming was a result of the inability of linear programming to offer viable solutions to some important problems. The first proposals methodologies for problems with integer variables were more adaptations of the simplex method than new theories. The main architect of the early integer programming was Ralph E. Gomory [2].

The Travelling Salesman Problem (TSP) is a classic problem for [2]: it is probably the best known and studied problem of integer programming. So this problem has infinitive particular cases that can be used to treat a wide range of varieties found in professional environments.

2.3 Methods of Resolution of the TSP

The TSP can, according to [9], be solved in several ways, among these some stand out like the exact methods (mathematical model and the method which uses a variant of the Branch and Bound) and heuristic methods, which provide approximate solutions. The advantage of the exact method is that it provides an exact solution to the problem, but depending on the complexity of it, to obtain such a solution becomes onerous by the computational point of view. Since the heuristics are not onerous, computationally speaking, but provide approximate solutions of the exact solution of the problem.

2.4 Mathematical Formulation of the TSP

There are several formulations for this problem. These formulations can be considered as canonical, such for its wide diffusion in the literature as for development of peculiar ways to characterize the problem (Goldbarg and LUNA, 2005).

Second [1], Dantzig, Fulkerson and Johnson in 1954, formulated TSP as a 0-1 programming problem on a graph G = (N, A) as follows:

$$\text{Minimize } z = \sum_{j=1}^{n}\sum_{i=1}^{n} c_{ij}x_{ij}$$

subject to:

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad \forall\, j \in N$$

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad \forall\, i \in N$$

$$\sum_{i,j \in S} x_{ij} \leq |S| - 1 \qquad \forall\, S \subset N$$

$$x_{ij} \in \{0,1\} \qquad \forall\, i,j \in N$$

Where x_{ij} is a binary variable where 1 means that the route passes by the edge formed between i and j, 0 means that the route does not pass by that edge. As c_{ij} represents the associated cost to the edge x_{ij}, in this case, by cost is defined the distance to be done on that edge. There are several algorithms for solving integer programming problems. The algorithm used to solve the problem formulated is based on enumerative techniques and the algorithm name is "Branch-and-Bound".

The algorithm of "Branch-and-Bound", according to [2], is based on a search tree where at each step all possible solutions of an instance of the problem are partitioned into two or more subgroups, each represented by setting a node of a decision tree.

The partitioning is performed according to some heuristics, which reduces the amount of searches to be done. After partitioning, limits are determined for each subgroup. The next solution space to be investigated is chosen with the lowest cost of the subgroups searched.

For the TSP, each solution is partitioned into two subgroups: those that contain the edge (i, j) and those that do not contain the edge (x ij

= x ij = 1 or 0). The process continues until a Hamiltonian cycle is obtained.

The implementation of the TSP with the algorithm of Branch-and-Bound has as input the amount of nodes from the network, and the cost matrix size "*n* x *n*". As output it has an optimal route from the first node. This algorithm is an exact method of searching, and in the worst case it can finish exploring all possible solutions.

According to [3], the routing problems deal mostly with trips or tours on demand or supply points. These points can be represented by cities, job stations, warehouses, etc.. Among the types of tours of the most important one is called Hamiltonian. Which was named after William Rowan Hamilton that, in 1857, created a game called *Around the World*. The game was consisted by a dodecahedron which had in each of its edges an important city back then. The challenge consisted in finding a route through those edges which had to begin and finish in the same city without repeating any of the other points (cities).

One of the solutions in the Hamiltonian game, paying homage to him, started being known as a Hamiltonian cycle. The first mention modernly known of the problem is due to Hassler Whitney, in 1934, in a paper of him in *Princeton University* [3].

2.5 Most Economic Insertion and Heuristic Improvement of 2-opt Route

The heuristic algorithm called the Most Economic Insertion, according to [4], considers a route within k nodes in the k^{th} iteration and determine which of the nodes, that are not in the route yet, could be the next to be inserted to the route (criteria of selection) and, thus determine the exact place where the node must be inserted. The Most Economic Insertion algorithm is described according to the following steps:

a) Starting with a sub-graph, which contains only the initial node.
b) Finding a k node such that the cost (c) is the minimum and has a sub-route i-k-i formed.
c) Finding (i, j) on the sub-route and k that are not there yet, such that c(i, k) + c(k, j) - c(i, j) be the minimum and, then, this k is inserted between i and j.
d) If a Hamiltonian cycle is formed, the algorithm has to be stopped. Otherwise, go back to item “c”.

The Heuristic Improvement 2-opt route was proposed by [6]. Its function, as the name says, is to hold if possible the improvement (optimization) of the route previously considered optimal. The Heuristic 2-opt improvement consists of the following steps:

A) Eliminate two (2) edges of the solution and re-insert two (2) edges in a crossing way.

B) If this change provides a better route than the previous one, i.e., if the distance to go reduce, keep the new route. Otherwise they should be chosen, again, two (2) edges for analysis.

If this procedure is repeated for all pairs of nodes of the problem, then it will reduce, if possible, the intersection between routes.

2.6 Tourism Bus Line

The Tourism Line, according to Curitiba’s City Hall [7], is a special bus route that circulates in the main tourist points of Curitiba. That makes it possible to know the most important parks, squares and attractions.

The visitors have to buy the ticket which provides their access to the mentioned bus, and the ticket also provides them to get on the bus in any of the points visited for the tourism bus line. It should be noted that according to the Figure 1, the buses in this tourism line are built to take the better photography and to view of all the attractions in the route.

Fig. 1. Curitiba's Tourism Line Bus (source: Curitiba's City Hall [7])

3 Methodology

3.1 Methodology used in the Problem Resolution

This work is classified in its purpose, as an applied research, which has as its basic motivation the solution of a concrete problem, practical and operational. Concerning the method and the way to solve the problem, this work can be classified as a quantitative research.

In order to obtain the distance within all 32 (thirty two) tourist points in the study, first it has been obtained the latitude and longitude values of each of the points, as shown in Table 1.

Table 1. Tourist Points Latitude and Longitude. Source: http://www.visitevinadelmar.cl.

Tourist Points	**Latitude**	**Longitude**
Oficina de Información Turística	-33.024164	-71.552619
Calle Valparaíso	-33.024875	-71.551790
Plaza María Luisa Bombal	-33.020778	-71.558923
Avenida Marina	-33.022266	-71.567928
Castillo Wulff	-33.019639	-71.565092
Castillo Ross	-33.019351	-71.564641
Caleta Abarca	-33.023777	-71.569161
Reloj de Flores	-33.025163	-71.567345
Calle Quillota	-33.022446	-71.547754
Palacio Rioja	-33.020179	-71.547132
Valparaíso Sporting Club	-33.018146	-71.540329
Sausalito	-33.011039	-71.537948
Plaza José Francisco Vergara	-33.024695	-71.551359
Teatro Municipal	-33.024893	-71.551466
Club de Viña del Mar	-33.025936	-71.552153
Estación de Viña del Mar	-33.026296	-71.552410
Parroquia N. Señora de los Dolores	-33.026692	-71.552453
Quinta Vergara	-33.027034	-71.555607
Anfiteatro	-33.026962	-71.555768
Palacio Vergara	-33.027393	-71.554127
Palacio Carrasco	-33.019927	-71.551166
Museo Fonck	-33.009959	-71.549149

Iglesia Las Carmelitas	-33.018740	-71.550908
Plaza Bernardo O´Higgins	-33.009689	-71.548698
Parque San Martín	-33.007836	-71.549878
Avenida Perú	-33.017372	-71.560221
Casino Municipal	-33.018092	-71.561208
Avenida Los Héroes	-33.019135	-71.561594
Reloj de Sol	-33.024137	-71.552238
Museo de Cañones Navales	-32.997722	-71.548462
Balneario Las Salinas	-32.969914	-71.545308
Playa Reñaca	-32.971660	-71.537819

Based on the values of latitude and longitude, it has measured the actual distances between all tourist points taken into pairs. To calculate the actual distance between all pairs of the tourist points were used the Google Maps® [5].

Next, the mathematical model was developed to solve the problem with the assistance of Lingo ® software, version 9.0. Due to the large amount of existing tourist attractions to draw one single route that contemplates the 32 (thirty two) tourist points, which makes it unviable to obtain an solution by the exact method, for this was used the heuristics of more economical insertion, being that solution improved by the improvement heuristic route-type 2-opt.

4. Results and Discussion

The Ruta del Pelícano is composed by eight (8) tourist points. This route is known to travel along the commercial or business attractions of Viña del Mar, and also points on the coast.

In Table 2, the tourist points visited on this route are exposed in optimized order, so the distance to visitation of the points is minimized. It is observed that the optimal distance is 5.54 Km (five kilometers and five hundred forty meters).

Table 2. Optimized route for ruta del pelicano. Source: data analysis

From	**To**	**Distance (Km)**
Oficina de Información Turística	Calle Valparaíso	0.18
Calle Valparaíso	Reloj de Flores	0.24
Reloj de Flores	Caleta Abarca	1.90
Caleta Abarca	Avenida Marina	0.22
Avenida Marina	Castillo Ross	0.85
Castillo Ross	Castillo Wulff	0.05
Castillo Wulff	Plaza María Luisa Bombal	0.80
Plaza María Luisa Bombal	Oficina Informaciones Turísticas	1.30
Total Distance		**5.54**

The Ruta del Cormorán, which covers 5 (five) sights, is characterized by a trip to the sporting heritage and tradition of the locality. Table 3 shows the optimal path to visit the sights of the Ruta del Cormorán. Through the above in that table, we find that the shortest distance to make up in order to visit all the sights of the Ruta is 7.85 km (seven kilometers, eight hundred and fifty meters).

Table 3. Optimized Route for Ruta del Cormorán. Source: Data Analysis

From	To	Distance (Km)
Oficina de Información Turística	Calle Quillota	1.70
Calle Quillota	Palacio Rioja	0.65
Palacio Rioja	Valparaíso Sporting Club	1.30
Valparaíso Sporting Club	Sausalito	1.10
Sausalito	Oficina de Información Turística	3.10
Total Distance		**7.85**

In the Ruta de la Gaviota, tourists have the opportunity to visit nine (9) sights. This Route is characterized by visiting historical sites that gave rise to Viña del Mar. The optimized route for these nine (9) sights to be visited is shown in Table 4. Through the mentioned table we can conclude that it is necessary to scroll 2.323 km (two kilometers, three hundred twenty-three meters) in order to visit all the sights that make up the Ruta de la Gaviota.

Table 4. Optimized Route for Ruta de la Gaviota. Source: Data Analysis

From	To	Distance (Km)
Oficina de Información Turística	Club de Viña del Mar	0.30
Club de Viña del Mar	Parroquia N. Señora de los Dolores	0.087
Parroquia N. Señora de los Dolores	Palacio Vergara	0.21
Palacio Vergara	Quinta Vergara	0.14
Quinta Vergara	Anfiteatro	0.016
Anfiteatro	Estación de Viña del Mar	0.40
Estación de Viña del Mar	Plaza José Francisco Vergara	0.50
Plaza José Francisco Vergara	Teatro Municipal	0.45
Teatro Municipal	Oficina de Información Turística	0.22
Total Distance		**2.323**

For the Ruta del Pinguino, according to the above in Table 5, we have optimized the distance to visit the 9 (nine) that make up such sights Ruta is 7.33 km (seven kilometers, three hundred and thirty meters).

Table 5. Optimized Route for Ruta del Pinguino. Source: Data Analysis

From	To	Distance (Km)
Oficina de Información Turística	Palacio Carrasco	2.00
Palacio Carrasco	Iglesia Las Carmelitas	0.13
Iglesia Las Carmelitas	Museo Fonck	1.00
Museo Fonck	Plaza Bernardo O´Higgins	0.35
Plaza Bernardo O´Higgins	Parque San Martín	0.30
Parque San Martín	Avenida Perú	1.70
Avenida Perú	Casino Municipal	0.12
Casino Municipal	Avenida Los Héroes	0.13
Avenida Los Héroes	Oficina de Información Turística	1.60
Total Distance		**7.33**

It must be noted that the Ruta del Pinguino is known as one who conducts a tour of the city's museums and beaches, and visit the center of Vina del Mar.
Finally the Ruta del Albatros, consisting of four (4) sights, is one that makes the ride along the coast coastal Viña del Mar, counting on their way to view the beautiful beaches of the town. The optimal distance to go this Route is 16.8 Km (sixteen kilometers and eight hundred meters), as shown in Table 6.

Table 6. Optimized Route for Ruta del Albatros. Source: Data Analysis

From	**To**	**Distance (Km)**
Reloj de Sol	Museo de Cañones Navales	3.90
Museo de Cañones Navales	Balneario Las Salinas	4.30
Balneario Las Salinas	Playa Reñaca	1.10
Playa Reñaca	Reloj de Sol	7.50
Total Distance		**5.54**

In addition to obtaining the minimum distances for the existing Routes, this study aims to establish a single routing, where the tourist has the opportunity to meet, albeit superficial, all 32 (thirty two) sights Viña del Mar at once. The optimal path that allows these visits so as to minimize the total distance to be traveled is shown in Table 7. It is noteworthy that such a path has a distance of 27.03 km (twenty-seven kilometers and thirty meters).

Table 7. Route of all the 32 tourist Points. Source: Data Analysis

From	**To**	**Distance (Km)**
Oficina de Información Turística	Teatro Municipal	0.22
Teatro Municipal	Calle Valparaíso	0.04
Calle Valparaíso	Reloj de Flores	0.24
Reloj de Flores	Avenida Marina	2.10
Avenida Marina	Caleta Abarca	0.22
Caleta Abarca	Castillo Wulff	0.70
Castillo Wulff	Castillo Ross	0.05
Castillo Ross	Avenida Los Héroes	0.70
Avenida Los Héroes	Avenida Perú	0.25
Avenida Perú	Casino Municipal	0.12
Casino Municipal	Plaza María Luisa Bombal	0.50
Plaza María Luisa Bombal	Calle Quillota	1.10
Calle Quillota	Palacio Rioja	0.65
Palacio Rioja	Valparaíso Sporting Club	1.30
Valparaíso Sporting Club	Sausalito	1.10
Sausalito	Parque San Martín	2.10
Parque San Martín	Playa Reñaca	4.90
Playa Reñaca	Balneario Las Salinas	1.10
Balneario Las Salinas	Museo de Cañones Navales	4.30
Museo de Cañones Navales	Plaza Bernardo O´Higgins	1.60
Plaza Bernardo O´Higgins	Museo Fonck	0.35
Museo Fonck	Iglesia Las Carmelitas	1.00
Iglesia Las Carmelitas	Palacio Carrasco	0.13
Palacio Carrasco	Reloj de Sol	0.45

Reloj de Sol	Plaza José Francisco Vergara	0.16
Plaza José Francisco Vergara	Estación de Viña del Mar	0.50
Estación de Viña del Mar	Parroquia N. Señora de los Dolores	0.05
Parroquia N. Señora de los Dolores	Anfiteatro	0.35
Anfiteatro	Quinta Vergara	0.02
Quinta Vergara	Palacio Vergara	0.14
Palacio Vergara	Club de Viña del Mar	0.30
Club de Viña del Mar	Oficina de Información Turística	0.30
Total Distance		**27.03**

5 Final Considerations

In this study, the TSP consisted by the necessity of determining the shortest path that could be done among all the tourist points which comprised each one of existent touristic routes in Viña del Mar. Moreover, all the 32 (thirty-two) tourist points from such place were gathered together in one unique route and, it was established the least route taking in all the aforementioned points.

When it was attempted to obtain the unique routing with the 32 (thirty-two) tourist points it was realized that due to the amount of points to compose such route, as well as the restrictions involved in the problem, that there were so many to consider that it turned up the problem was unpractical, thus makes not being possible an exact solution, since that could become too onerous in the realm of computing. An alternative to obtain one optimal approximated solution is using heuristic methods, like the heuristic of the cheapest insertion.

When adding up one by one the total distance, which was already optimized, to be held for each one of the 5 (five) routes approached in this study (Ruta del Pelícano, Ruta del Cormorán, Ruta de la Gaviota, Ruta del Pinguino and Ruta del Albatros) it is obtained the distance of 28.583 Km (twenty-eight kilometers, five hundred and eighty-three meters).

By contrast, when turning all the 5 (five) routes into only one route, it was achieved one total distance of 27.03 Km (twenty-seven kilometers and thirty meters), i.e., such routing is 1.553 Km (one kilometer and five hundred and fifty-three meters) lower than the total distance that it has been applied by the 5 (five) existent routes.

It is noteworthy to say that the unique route, however subject to pass through the 32 (thirty-two) tourist points, did not have an extensive total distance to be traveled, this way such route is feasible to be undertake by the tourists as they arrive in the city of Viña del Mar. In this way, the visitors have the opportunity to know within only one day all the attractions of the city and, then, to choose to take another visit to the most interesting place according to themselves.

Finally it is worth to mention, according to study, there is an opportunity to the local authorities establishes a tourism bus line, as those found in the capital cities of Curitiba, Florianópolis and Porto Alegre, all of them situated in southern Brazil, in order to pass through the itinerary described in Table 7, providing the tourists a city-tour with the tourist points of Viña del Mar. So that such authorities could increase the satisfaction of their visitors, as well as increasing the city incomes through the money to be raised by selling the tickets to such buses.

References

[1] N. Christofides, A. Mingozzi, P. Toht, "The Vehicle Routing Problem," *In: Combinatorial Optimization*. New Jersey: John Wiley and Sons, 1979. pp. 315-338.

[2] E. C. Colin, *Pesquisa Operacional*. Rio de Janeiro: Editora LTC, 2007.

[3] C. M. Goldbarg, H. P. C. Luna, *Otimização Combinatória e Programação Linear*. Rio de Janeiro: Editora Campus, 2005.

[4] B. Golden, L. Bodin, T. Doyle, W. Stewart Junior, "Approximate traveling salesman algorithms," *Operations Research*, vol. 28, no. 3, part II, pp. 694-711, 1980.
[5] Google Maps. Available at: <http://maps.google.com.br/maps>. Accessed in 23 nov 2011.
[6] S. Lin, B. W. Kernighan, "An Effective Heuristic Algorithm for the Traveling Salesman Problem," *Operations Research*, vol. 21, pp. 498-516, 1973.
[7] Prefeitura Municipal de Curitiba. Available at: <http://www.urbs.curitiba.pr.gov.br/PORTAL/linha_turismo/>. Accessed in 30 nov 2011.
[8] A. de L. Puccini, N. D. Pizzolato, *Programação Linear*. Rio de Janeiro: Editora LTC, 1990.
[9] M. T. A. Steiner, *Otimização em Redes*. 30 mai – 02 set 2011. 88 f. Notas de Aula. Apresentação no Microsoft Powerpoint®.

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