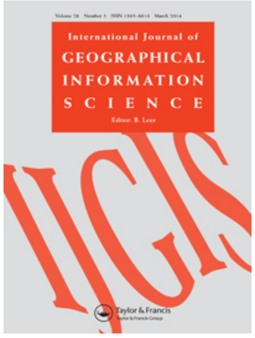

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The use of GIS tools to support decision-making in the expansion of chain stores

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This article deals with a network competitive localization problem in which a firm seeks to determine the location of a new facility, which competes with all the facilities operating in the market, both belonging to the same firm and to the competing firms. In this context, two frequently conflicting objectives are involved: maximization of the total market share captured by the firm and minimization of market share losses for its existing facilities due to being captured by the new facility (cannibalization). We formulate the location problem as a multi-objective optimization model. Some GIS tools that provide some maps representing the market share and the cannibalization effect are proposed. This allows for the visualization of the effects produced by the opening of a new facility in the market and the trade-offs between the objectives. Finally, the advantages of using these tools have been shown by means of an application to a real data case.

Keywords: competitive location; proportional preferences; franchise; cannibalization; multi-criteria

1. Introduction

Competitive location models represent situations in which two or more firms compete in providing goods or services to clients (for an overview of these models, see Hakimi (1990), Eiselt and Laporte (1989, 1997), Eiselt *et al.* (1993), Friesz *et al.* (1988), Plastria (2001), and Kress and Pesch (2012)). In a competitive location problem the objective of selecting the location of additional facilities in a chain of stores with the same owner is the optimization of a measure of the chain's performance. Normally, the firm seeks to maximize its profit or revenue, or its market share (the demand captured by the facilities in the chain). In a franchise distribution system, where the facilities in the chain do not necessarily have the same owner, the objective of the franchisor firm may be in conflict with the individual goal of the franchisee; which is to optimize a performance measure for a specific facility. In this situation, the market share losses for the chain's existing facilities due to being captured by the new facility are known as cannibalization. In this case, certain equilibrium among the objectives of the franchisor and the objectives of the franchisees is desirable. Two objectives, normally in conflict, are involved: the maximization of the firm's market share and the minimization of cannibalization.

Due to the multi-objective nature of these problems, multi-criteria optimization techniques become suitable methods for solving them. Different procedures for finding Pareto

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optimal solutions can be applied (see Ballestero and Romero (1998) and Miettinen (1999)). Weighting methods assign a weight to each objective function and a weighted sum of these functions is optimized. The weight assigned to the cannibalized demand is often interpreted as a cost for the franchisor or a compensation payment to the franchisees (Current and Storbeck 1994, Pelegrín *et al*. 2012). In the constraint procedure, one of the objective functions is optimized while the rest of them are included in the set of constraints which guarantee that those functions reach values considered sufficiently good. So, if α belongs to the range of values taken from cannibalization, an efficient solution is obtained solving the problem of maximizing the market share, subject to cannibalization being lower than or equal to α (Drezner 2010). Lexicographical approaches assume a priority order for the objectives (Plastria 2001, Fernández *et al.* 2007). The solution is provided by the resolution of a sequence of optimization problems corresponding to the different priority levels. An alternative procedure for solving multi-criteria decision problems is goal programming. This consists of minimizing a function of the unwanted deviations between the achieved values and the target levels for the attributes; the decision-maker does not try to optimize anything but instead tries to achieve attribute values as close as possible to their aspiration levels. Strategies that focus on protecting the existing facilities in the chain or guaranteeing the survival of new facilities may be considered. For instance, a certain level of revenue can be imposed for the existing facilities individually or as a group, and a lower boundary of the revenue obtained by the new facilities may be fixed. A strategy aimed at avoiding the risk associated with competitor reactions is presented by Plastria (2005), who proposes considering the worst case future scenario, in which the competitors reach the best position (quality level), and secure the demand captured by the new facility.

Competitive location models incorporate several aspects related to consumers and providers of goods and services. First, the behavior of customers must be modeled, aspects such as the type of goods, the number of facilities and their quality and location, may influence customer decisions. Essential goods must be completely consumed, meaning that consumers satisfy all their demand, which is totally captured by the firms operating in the market. Inessential goods are dispensable, and customers may not use all of their buying power if they do not consider that facilities are sufficiently accessible or attractive. The term *reservation distance* is used to designate the maximum distance that a customer is willing to travel to obtain goods or services. Another aspect that may be considered is the expansion of the demand generated by new facilities. In some models, the expenditure is assumed to be a function of the number of facilities operating in the market within the consumers' reservation distance (Ghosh and Craig 1991).

If the distance to facilities is considered the only decision criterion for consumers, the simplest customer choice rule is the binary one, representing the 'all or nothing' behavior. Other customer choice rules replace this hyper-sensitive consumer conduct implicit in the binary rule with a threshold sensitivity behavior: a customer uses firm A exclusively, only if the distance from this customer to the competitors exceeds the distance to firm A in an amount greater than or equal to a threshold, and the demand captured by each firm in the *doubtful zone* (or *shared zone*) is given by a non-increasing function of the travel distance (Devletoglou 1965, Devletoglou and Demetriou 1967). The partially binary choice rule distributes the demand among the closest facilities of the firms operating in the market, whereas the proportional choice rule distributes the demand among all facilities (Hakimi 1990). A gradual sensitivity behavior can be modeled with a *coverage decay function* (Berman *et al.* 2003, 2010) or, using a more competitive term, a *capture decay function*.

Several known customer choice rules presented in the literature can be taken as particular cases of a general capture decay function.

In this article we consider essential goods and use the Huff model (Huff 1964), which involves a proportional choice rule. Following this model, we assume that the probability of a customer at point v_i visiting a facility at x_j with quality level a_j is an increasing function of a_j and a decreasing function of the distance from v_i to x_k.

We integrate a competitive location model involving both objectives, the maximization of the firm's market share and the minimization of cannibalization, in a GIS tool that provides information about suitable locations in a multi-criteria decision problem. Previous works where location models are integrated into a GIS framework can be found in Spaulding and Cromley (2007) and Suárez-Vega *et al*. (2011, 2012) as well as in references cited by Church (2002) and Murray (2010). This work is connected with the papers by Suárez-Vega *et al*. (2011, 2012) but differs from them in several aspects. In Suárez-Vega *et al*. (2011) the cannibalization is not considered, and a multi-criteria decision analysis (an Analytical Hierarchy Process (AHP) technique) is applied to find the most promising locations to open a new facility, considering the demand captured by the firm, the distance from the facility to the main roads, the land use, the slope of the terrain and the distance to the distribution centers as relevant attributes in the decision-making. In Suárez-Vega *et al*. (2012) market share and cannibalization are included into the model, but the customer choice rule is binary and Euclidean distances are used. In the present article, a proportional Huff model considering network distances is solved and a different multi-criteria focus is considered. This approach incorporates the use of the weighting and constraint techniques to solve a multi-criteria optimization problem in a GIS environment.

We consider the problem of locating a new facility in a market where other competing facilities exist. This new facility may be installed in the neighborhood of a network. Some conditions, such as a minimum distance to the existing facilities or that which guarantees the survival of the stores belonging to the same chain, could be imposed. We develop GIS tools that provide both a map representing the market share and a map showing the cannibalization effect.

These maps provide significant aid to the decision-maker in the location problem, not only making location findings that maximize the separate objectives but also the comparison of the suitability of the different areas in the feasible region. GIS tools allow the incorporation of forbidden regions and the elimination from the feasible region of those areas where the cannibalization is greater than certain desired values. GIS also allows the decision-maker the visualization of the effects produced in the market by the opening of a new facility and the trade-offs between objectives.

The rest of this article is organized as follows. Section 2 contains the formulation of the problem as a multi-objective competitive location model and the description of the process to integrate the model in a GIS environment. Section 3 includes an application of the GIS tool described in Section 2 to determine the location of a new store on the island of Gran Canaria (Spain). Finally, Section 4 contains the conclusions.

2. Location model and GIS processing methodology

The decision problem is formulated as a multi-objective optimization model where the objectives are the maximization of the market share and the minimization of cannibalization. This model is described in Section 2.1. In Section 2.2, we explain how a GIS tool incorporating this location model is built.

2.1. The competitive location model

A chain (or firm) A operates in the market competing with firm B and wants to determine the best location for an additional facility. Two objectives are considered; the first of which is the maximization of the total demand captured by chain A's facilities (i.e., the maximization of the market share), whereas the second objective is to minimize cannibalization (i.e., the minimization of market share loss suffered by the existing facilities in the chain when the new facility is opened). Additionally, we consider the minimization of individual cannibalization, that is, the loss of market share of each existing facility belonging to firm A produced by the opening of a friendly new facility.

The market is represented by a network. Let $N(V,E)$ be a weighted network with node set $V = \{v_i\}_{i=1}^n$ and edge set E, where each node v has associated a weight $w(v)(\geq 0)$ and each edge $e = [v_i, v_j] \in E$, with $v_i, v_j \in V$, has associated a cost $c(e)(\geq 0)$. It is assumed that $N(V,E)$ represents a market where $w(v)$ is the demand (or buying power) at node v and $c(e)$ represents the unitary transportation cost along the edge e. For points $x, y \in N(V,E)$, $c(x,y)$ is the cost of the minimum cost path joining x and y.

The attraction felt by customers at node v towards a facility j at $x_j \in N(V,E)$ with quality level a_j is given by

$$a_{vj} = \frac{a_j^\alpha}{c(v,x_j)^\lambda}, \tag{1}$$

where α and λ are parameters that reflect the effect on the customer's behavior on size and transportation cost, respectively.

Let $V^d \subseteq V$ be the set of network nodes where demand exists $(w(v) > 0)$, $V^A(V^B) \subseteq V$ the set of points where a chain A's (B's) facility already exists and $c_{ij} = c(v_i, v_j), v_i, v_j \in V$. Then, following the Huff model, the market share captured by an existing facility with quality level a_k located at point $v_k \in V^A \cup V^B$ is given by

$$MS_k = MS(v_k, a_k) = \sum_{v_i \in V^d} w(v_i) \frac{\frac{a_k^\alpha}{c_{ik}^\lambda}}{\sum_{v_j \in V^A \cup V^B} \frac{a_j^\alpha}{c_{ij}^\lambda}}. \tag{2}$$

Then, previous to the entry of a new facility in the market, the market share for chains A and B are

$$MS^A = \sum_{v_k \in V^A} MS_k \quad \text{and} \quad MS^B = \sum_{v_k \in V^B} MS_k, \tag{3}$$

respectively.

The market share captured by a new facility with a given quality level a_0 located at point $x_0 \in N(V,E)$ is given by

$$MSN(x_0) = \sum_{v_i \in V^d} w(v_i) \frac{\frac{a_0^\alpha}{c(v_i,x_0)^\lambda}}{\frac{a_0^\alpha}{c(v_i,x_0)^\lambda} + \sum_{v_k \in V^A \cup V^B} \frac{a_k^\alpha}{c_{ik}^\lambda}}. \tag{4}$$

After the location of the new facility, the market share captured by an existing facility with quality level a_k and located at v_k is given by

$$MSA_k(x_0) = MSA_k(v_k, a_k, x_0) = \sum_{v_i \in V^d} w(v_i) \frac{\frac{a_k^\alpha}{c_{ik}^\lambda}}{\frac{a_0^\alpha}{c(v_i,x_0)^\lambda} + \sum_{v_k \in V^A \cup V^B} \frac{a_k^\alpha}{c_{ik}^\lambda}}, \quad \forall v_k \in V^A \cup V^B. \tag{5}$$

The total market share obtained by chain A when a new friendly facility is located at point x_0, given the quality level a_0, is

$$MSA^A(x_0) = MSN(x_0) + \sum_{v_k \in V^A} MSA_k(x_0). \tag{6}$$

Under Huff model assumptions, customers patronize all the facilities in the market in proportion to the attraction they perceive from them. This implies that the new facility will take demand from both the friend and rival stores. The loss of market share of an existing facility $v_k \in V^A$ due to the incorporation of the new facility (cannibalization) is calculated as

$$Can_k(x_0) = MS_k - MSA_k(x_0), \forall v_k \in V^A. \tag{7}$$

Therefore, the total cannibalization suffered by firm A's facilities is: $Can(x_0) = \sum_{v_k \in V^A} Can_k(x_0)$.

The following objectives are considered:

First objective: firm A's market share maximization

In this case, firm A seeks to determine the location of a new facility, given its quality level a_0, that maximizes its total market share. This problem can be formulated as:

$$\max_{x_0 \in F} MSA^A(x_0),$$

where F is the feasible region containing all the potential locations for establishing the new facility. Note that under the assumption of a constant marginal cost, maximizing profit is equivalent to maximizing captured demand.

Second objective: cannibalization minimization

Cannibalization is understood as the portion of the new facility's market share captured from the existing facilities belonging to chain A. Therefore, the problem for chain A is to find the feasible location, x_0, given the quality level a_0, which minimizes the total cannibalization. That is:

$$\min_{x_0 \in F} Can(x_0).$$

The bi-objective problem

Therefore the bi-objective problem to be solved is the following:

$$\left(\max_{x_0 \in F} MSA^A(x_0), \min_{x_0 \in F} Can(x_0) \right).$$

Due to the conflict between the objectives, normally there is not a point which optimizes both objective functions simultaneously, that is, the ideal point given by

$$\left(MSA^{*A}, Can^{*}\right) = \left(\max_{x_0 \in F} MSA^{A}(x_0), \min_{x_0 \in F} Can(x_0)\right)$$

is unreachable. In this case we seek Pareto optimal solutions. A payoff matrix is built from the solutions obtained when the ideal point is calculated. Row i of the payoff matrix contains the objective values for the feasible point that optimizes objective i. The ideal point is the main diagonal of this matrix. Observe that, if for any of the two problems giving the ideal point, a unique optimal solution exists, these two solutions are Pareto optimal.

In order to find efficient solutions (Pareto optimal solutions) to the bi-objective optimization problem we can apply, among other procedures, the weighting method (Zadeh 1963) and the constraint method.

To obtain an efficient solution via the weighting method, we solve the problem

$$\max_{x_0 \in F} w_1 MSA^{A}(x_0) - w_2 Can(x_0),$$

where w_1 and w_2 are positive weights. For this method, the weight assigned to cannibalization may be interpreted as a cost γ per unit of demand missed due to the cannibalization effect. In this case we transform the bi-objective problem into the following single objective problem:

$$\max_{x_0 \in F} \Pi(x_0) = MSA^{A}(x_0) - \gamma Can(x_0). \tag{8}$$

The cannibalization cost value, γ, must be chosen by the firm managers to reflect the firm's perception of market loss for its existing facilities. A value of $\gamma = 0$ means that the cannibalization effect is not taken into account, while high values of γ indicate a protectionist policy with respect to the established facilities. Note that the function $\Pi(x_0)$ must be considered a goodness index, instead of a capture measure, that allows us to compare the suitability of location x_0 with respect to the rest of the feasible sites. However, if γ represents the monetary cost per unit of loss for firm A's existing facilities, $\Pi(x_0)$ can be interpreted as a profit function.

We can also obtain an efficient solution via the constraint method. Thus, solving any of the following problems

$$\max_{x_0 \in F} MSA^{A}(x_0) \quad \textit{subject to}\, Can(x_0) \leq Can,$$

$$\min_{x_0 \in F} Can(x_0) \quad \textit{subject to}\, MSA^{A}(x_0) \geq MS,$$

where Can and MS are constants belonging to the range of values of $Can(x_0)$ and MSA (x_0), respectively. This range of values is obtained from the payoff matrix.

We can modify the previous formulation of the multi-objective problem by incorporating the individual requirements for the chain. Now we consider the following problem with $1 + |V^{A}|$ objectives:

$$\underset{x_0 \in F}{opt}\left(MSA^A(x_0), \overline{Can}(x_0)\right) = \left(\max_{x_0 \in F} MSA^A(x_0), \min_{x_0 \in F} Can_1(x_0), \ldots, \min_{x_0 \in F} Can_{|V^A|}(x_0)\right).$$

To obtain Pareto optimal solutions, we apply the constraint method maximizing the total market share and imposing the cannibalization for any facility belonging to firm A to be less than or equal to a prefixed survival level. In this case we are limiting the loss of market share resulting from the entry of a new facility, discarding any location that leads to a loss larger than a certain prefixed value or *survival level*. Then, we solve the following problem for a collection of survival levels α_k:

$$\begin{aligned} &\max_{x_0 \in F} MSA^A(x_0) \\ &Can_1(x_0) \leq \alpha_1 \\ &\ldots\ldots\ldots\ldots\ldots \\ &Can_{|A|}(x_0) \leq \alpha_{|V^A|}. \end{aligned}$$

2.2. GIS processing methodology

We integrated the competitive location model described previously in a GIS framework. This framework was developed using ArcGIS 9.3®, but the tools employed are based on standard spatial operations that can be perfectly replicated in any other GIS software. Figure 1 shows the flowchart representing the different process stages facing the location problem from the multi-objective methodology. The initial inputs were vector layers containing the information of the market. The outputs were raster maps containing the score for the different zones of the feasible region according to the results provided by the two multi-objective methods considered in this article.

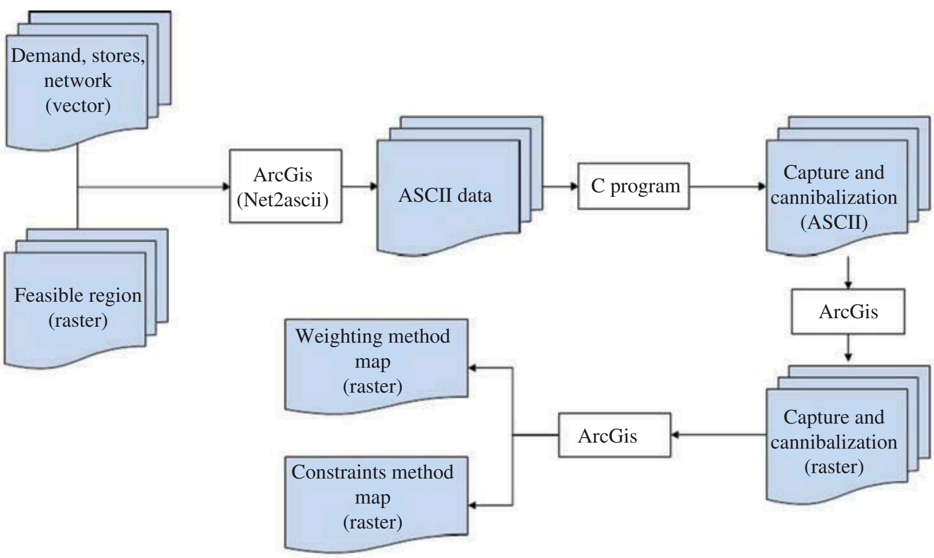

Figure 1. Flowchart reflecting the processes involved in solving the problem.

First, the Net2ascii ArcGis tool developed by Suárez-Vega *et al*. (2011) by means of the ArcGis Model Builder was used for converting information of the vector layers containing the transportation network, the demand nodes (with their population), and the existing facilities (with their sales surfaces) into ASCII files. We considered that all the arcs belonging to E are straight lines, so polylines were not allowed. Then, for each arc, the network layer must store its length, type of road, and end points identification. This tool also used a raster map, representing the feasible region, which was used for restricting the set of pixels belonging to the feasible region F. Although in a network location problem the feasible set F coincides with the network $N(V,E)$, we considered the potential location set as a buffer around the network. Moreover, we eliminated from this buffer those areas that *a priori* were not adequate for locating the new store.

Then a program written in C (available as an executable file) was used for obtaining the estimated market share for the facilities, before and after the location of the new store, as well as the cannibalization produced over the existing chain A's facilities. The 'C' coded algorithm used is a modified version of that proposed by Suárez-Vega *et al*. (2011) for obtaining firm A's total market share. In the first version of the program, formula (4) was used for obtaining total market share of a firm A which enters the market, opening a facility that competes with other existing facilities in the market. In this new version, the program calculates the estimated capture for each facility operating in the market, both before (using (2)) and after (using (4) and (5)) the opening of the new store. This new reformulation allows us the possibility of calculating (using (7)) the cannibalization suffered by each existing facility belonging to firm A, and of course, the total cannibalization suffered by firm A. This information was stored in ASCII files which contained, for each pixel of the feasible region, the corresponding estimated value. This C program also provided the estimated capture of each of the chain A's facilities before the location of the new store.

Next, the ASCII files containing the market share and cannibalization estimation were converted into raster maps by means of the corresponding ArcGis standard conversion tool. These maps can be used for showing the spatial distribution of each of the objective functions as well as for carrying out the two multi-objective analyses proposed in this article.

The weighting method was easily implemented by means of the ArcGis standard weight sum tool giving a weight equal to one for the chain A's total capture map and a weight equal to $-\gamma$ to each of the individual cannibalization maps. In order to apply the constraint method, it was sufficient to remove from the individual cannibalization maps those areas with cannibalization level higher than the prefixed threshold for each store. Combining all these reclassified cannibalization maps, a new map of feasible areas was obtained. Analyzing the total estimated capture for chain A over this new map, the most promising locations for the new store were identified.

ArcGis allows for the programming of customized tools using Visual Basic for Applications (VBA). So we developed a tool which, by clicking on a point in the feasible region, summarizes the values for the different variables calculated by means of the 'C' program. Moreover, in order to evaluate the profitability of each facility, the captures per square meter of sales surfaces, both before and after the location of the new facility, are shown.

3. A practical application

In order to show how the tools described above provide significant aid to the decision-maker in location problems, these were used to find the most promising locations for a

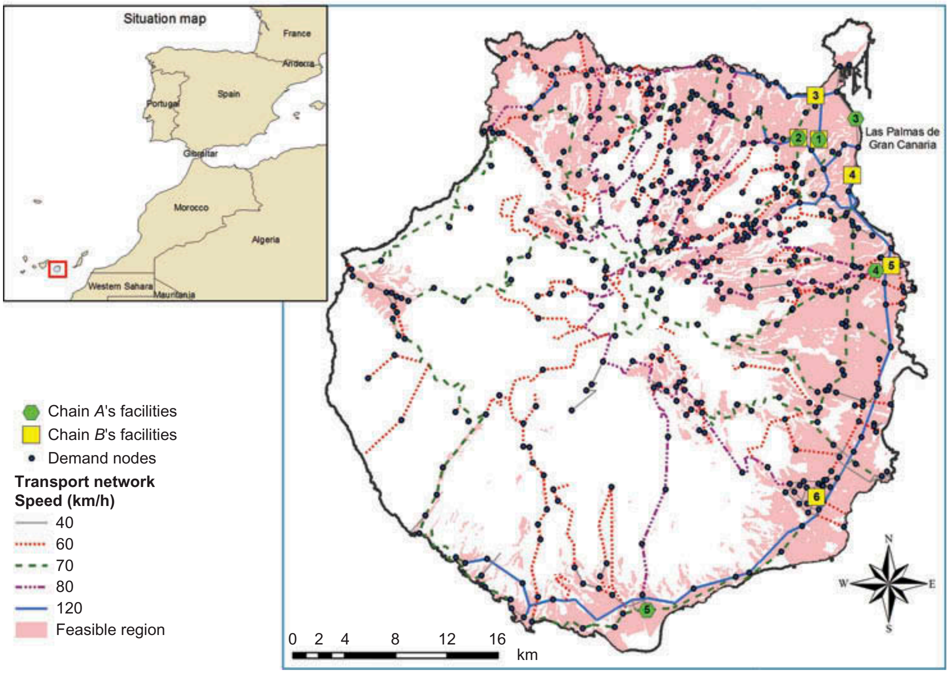

Figure 2. Situation map of Gran Canaria Island and market description for the application.

new hypermarket on the Spanish island of Gran Canaria. Gran Canaria is one of the islands in the Canarian Archipelago and a popular European tourist destination. Its capital is the city of Las Palmas de Gran Canaria, in the northeast of the island, which has one of the largest ports in the Atlantic, the Port of La Luz y Las Palmas. This island is of a circular shape with a radius of 25 Km and a population of 763,082 inhabitants (2006 Population Census). Figure 2 shows the geographical zone in which our problem takes place. Since the studied region is an island, it provides an almost perfect geographical framework for this kind of analysis.

It should be noted that 51.7% of the population and 59.88% of the sales surface on the island are concentrated in the capital. The remainder of the hypermarkets and an important part of the demand are distributed on the eastern and southern sides of the island. The central and western parts of the island are mountainous areas with low population densities.

In this application, the quality level is measured on the basis of hypermarket's sales surface area (m^2), and we assume that the size of the new hypermarket is known. Although the hypermarkets sell a variety of goods, we have only considered necessity goods, so that the essential demand assumption holds.

3.1. The data

The network was stored in a line layer that was built on an approximation of the main roads on the island. The network contains 913 vertices and 1060 arcs. The type of road and the length of each edge were known and the transportation cost was calculated considering the speeds corresponding to the type of road (in Figure 2 roads are drawn with respect to their speed classification). Note that if the point is off the road but inside the buffer, the cost associated to reach the closest arc is calculated considering a speed of 30 Km/h.

As statistical data on the average expenditures in the Canaries are aggregated at a provincial level, i.e., they are the same for the whole Island, we have considered the population of the demand points to represent their buying power. In this context, the estimated captures, as expressed by inhabitants, can be considered proportional to the expected income.

In order to distribute the demand along the network nodes, the least aggregated census units for which official population data is available in Spain was considered. The population of each administrative unit was aggregated into the centroid of the corresponding polygon. Then, the population of each centroid was allocated to the closest network vertex. The result was a demand node set, V^d, containing 509 vertices and whose distribution is shown in Figure 2.

In 2009, eleven hypermarkets existed in Gran Canaria. Chain A is a national distribution group specialized in 'proximity supermarkets' and at that time owned five hypermarkets (A1, A2, A3, A4, and A5 in Figure 2). The rest of the stores belong to three international distribution groups (grouped in chain B), with one (B2), another (B5) and four (B1, B3, B4, and B6) stores, respectively. Note that the couples A1–B1 and A2–B2 coincide because two competing hypermarkets exist very close to those network nodes. The sales surfaces for chain B's existing hypermarkets were 6739, 5000, 9927, 5200, 11,108, and 6750 m^2. The sales surfaces for the chain A's facilities are shown in the second column of Table 1.

The feasible region was built combining both a slope map and a land-use map. To prevent building problems, areas with slopes greater than 12% were discarded. According to the land-use map, different zones considered not to be appropriate locations for a hypermarket (e.g., water bodies, natural protected areas) were also eliminated from the feasible map. Finally, as an imposed condition according to chain A's location policy, exclusion areas within a radius of 1 Km around each facility operating in the market (friends and rivals included) were removed from the feasible region map as well. The feasible region is shown in Figure 2.

To illustrate the possibilities of the proposed tool outputs, the location of a new facility belonging to chain A with a size of 3099 m^2 (the average size of chain A's existing facilities) is considered. In order to avoid a division by zero error in (1), which occurs when two points coincide, a fixed amount 0.1 is added to the transportation cost. The weights used for calculating the attraction are $\alpha = 0.525$ and $\lambda = 2.983$. These values were estimated by Suárez-Vega *et al*. (2011) from a survey made in 2007 in Gran Canaria and formed by 812 valid questionnaires.

Table 1. Initial market situation for chain A.

Chain A hypermarkets	Size (m^2)	Estimated capture	Market share (%)	Cap/m^2
$A1$	4191	55,908.02	7.33	13.34
$A2$	2500	40,562.95	5.32	16.23
$A3$	2500	71,057.32	9.31	28.42
$A4$	3351	53,552.80	7.02	15.98
$A5$	2951	47,120.73	6.18	15.97
Total chain A		268,201.82	35.15	17.31

3.2. Analysis procedure and results

The first information we obtain by running the 'C' program is the estimated capture for each existing facility belonging to chain *A*. In Table 1, both the estimated capture and the capture per square meter for chain *A*'s existing facilities are presented (columns three and four, respectively). Previous to the new facility location, chain *A* had a market share of 35.15% and an average capture per square meter of 17.31. This ratio can be considered as a profitability index for the facilities after the location of the new store.

Alternatively, the results obtained by the 'C' program can be converted into raster maps. Figure 3 shows a map representing, for each point in the feasible region, the total capture estimated for chain *A*. Analyzing this map, two promising areas appear: one in the capital of the island (Zone 1) and another in the southwestern part of Gran Canaria (Zone 2). In the capital a high concentration of hypermarkets already exists, three belonging to chain *A* and four to chain *B*. Nevertheless, the difference of population density with the rest of the island is so high that the location of a new hypermarket here seems to be suitable. The southern alternative is a high-populated area where only one competing store exists. However, if the maximization of the total market share is the only criterion for chain *A*, the best location for the new facility is in the capital of the island, near facility B3 (the triangle in Figure 3). A new facility at this location implies that chain *A* obtains a 25.17% increase of market share, improving the capture by m^2, which passes from 17.31 to 18.06.

In this case, the location that maximizes chain *A*'s total capture coincides with the site where the capture for the new facility is maximum. So, this location satisfies the interest of both chain *A* and the promoter of the new facility. But, what is the effect of the location of this new hypermarket over chain *A*'s existing facilities? Figure 4 can help the decision-

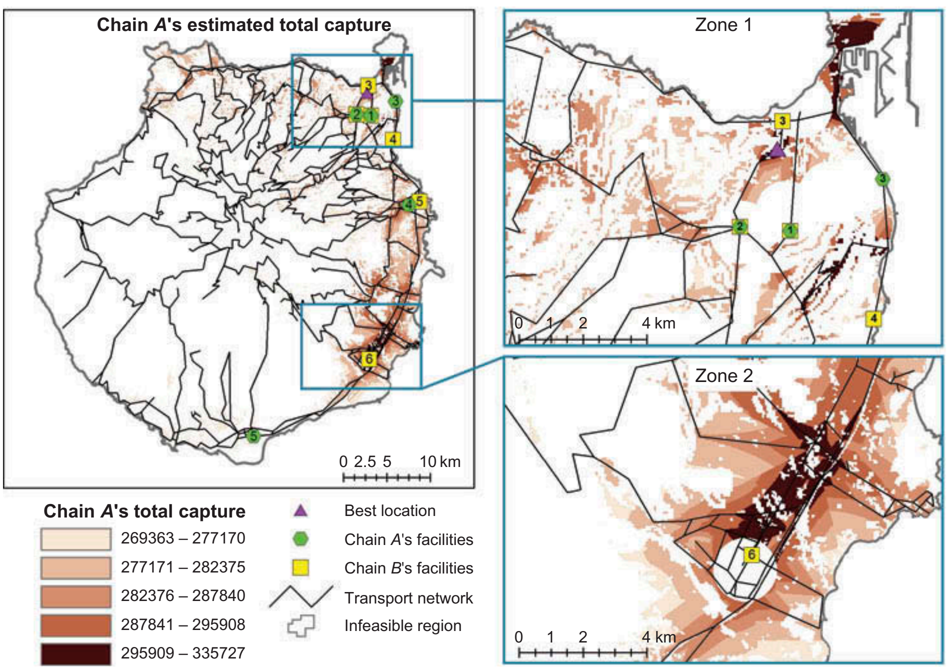

Figure 3. Total capture map for chain A and detailed view for the two most promising zones.

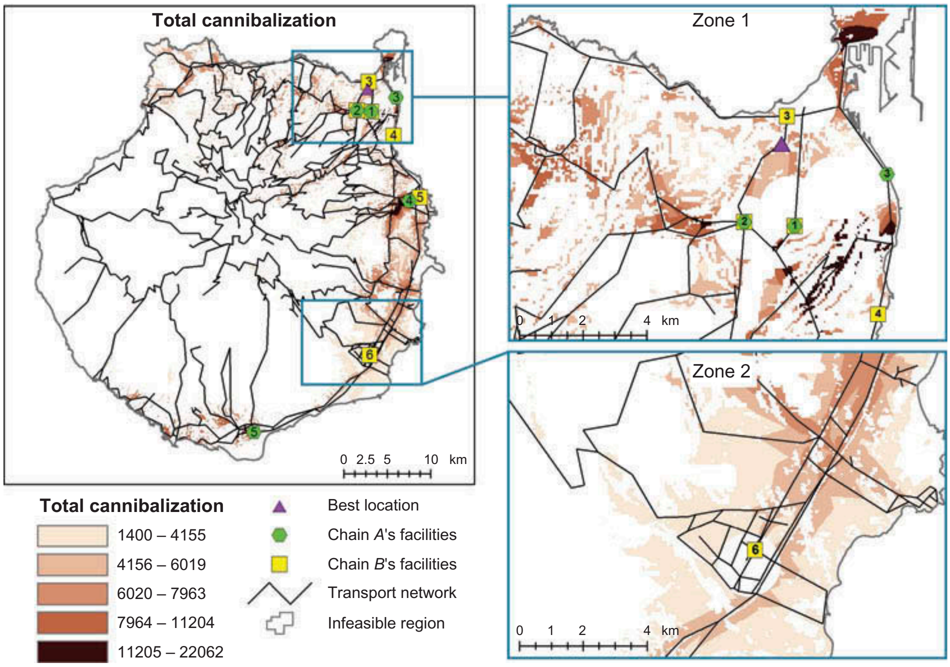

Figure 4. Total cannibalization map and detailed view for the two most promising zones.

maker to evaluate the total cannibalization. Analyzing the cannibalization suffered in the two most promising areas for locating the new store, we can see that in Zone 1 a medium level cannibalization exists, whereas in Zone 2 cannibalization has a low-medium level. The site selection for the new facility may depend on the perception of the cannibalization by firm *A*'s managers. To help decision-making, we propose applying the bi-objective resolution procedures described in Section 2, the weighting and the constraint methods.

When the decision-makers have an idea of the cannibalization cost (perhaps from a monetary point of view) the weighting method may be more suitable. Assuming that the decision-makers assigns a cost, γ, per unit of demand missed due to the cannibalization effect and, using the maps obtained by the 'C' program, score maps (calculated using (8)) can be obtained. Figure 5 shows the goodness index maps for cannibalization cost $\gamma = 1$ and $\gamma = 10$. Location 1 (in Zone 1) results in a very robust option, because it is also the location that maximizes the goodness index (objective function in the weighting method) for reasonable values of γ. A cannibalization cost of 9.5, which is something unrealistic, is necessary to change the most promising site from Location 1 to Location 2 (around 30 Km further away).

The weighting method considers the total cannibalization, that is, the aggregate effect of the new store over all the existing friendly facilities. Nevertheless, for some situations, resolving the location problem using the total cannibalization may not be convenient, for example, when, in order to guarantee the survival of each friendly store, upper individual cannibalization thresholds are imposed. In this case, the constraint method for solving multi-objective optimization problems is better indicated. We define the cannibalization threshold or survival level as the maximum percentage of losses with respect to the captures that the facilities obtained previous to the location of the new store.

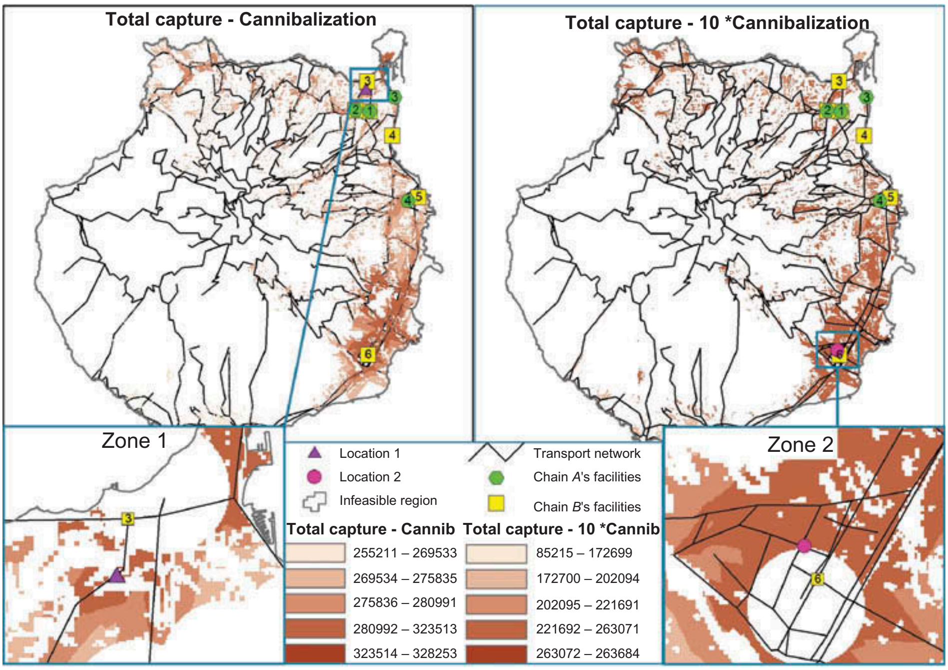

Figure 5. Score maps for the weighting method considering two different cannibalization costs.

So, in order to analyze the evolution of the solution with respect to the variation of the cannibalization thresholds, the problem was solved considering thresholds varying from 1% to 30% with increments of 1%. The same threshold was considered for all the existing facilities. When very low-cannibalization levels are fixed, from 1 to 4%, the best solution for the new facility is located in the southern part of the island (around the site identified in Figure 5 as Location 2) with captures from 306,549 to 308,087. For a 5% cannibalization threshold the most promising location becomes the capital of the island (near Location 1 in Figure 5) with an important increase in captures. However, for losses higher than or equal to 6% the proposed location is Location 1, which is also the site where chain *A*'s total capture is maximized.

As conclusion, results from both the weighting and the constraint methods suggest that the location that maximizes chain *A*'s total capture is quite a robust option. A movement of the most scored area from Zone 1 to Zone 2 (30 km further away) occurs only if a very high-cannibalization cost or a very low-cannibalization threshold is imposed.

Figure 6 shows the summary window that appears by clicking on the site marked as Location 1 in Figure 5. First, the coordinates of the point analyzed appear. Then an analysis of chain *A*'s total capture, both before and after the location of the new store is presented. In order to compare the suitability of the point analyzed, the maximum estimated capture for chain *A* is also shown. In this case, as we pinpointed the location that maximizes this objective, both values (After and Max. after) coincide. In all cases, for the existing facilities belonging to firm *A* and for the new one, both the capture and the ratio capture per square meter of sales surface (in brackets), are shown. Comparing this ratio before and after the location of the new facility, one can see that chain *A* increases its

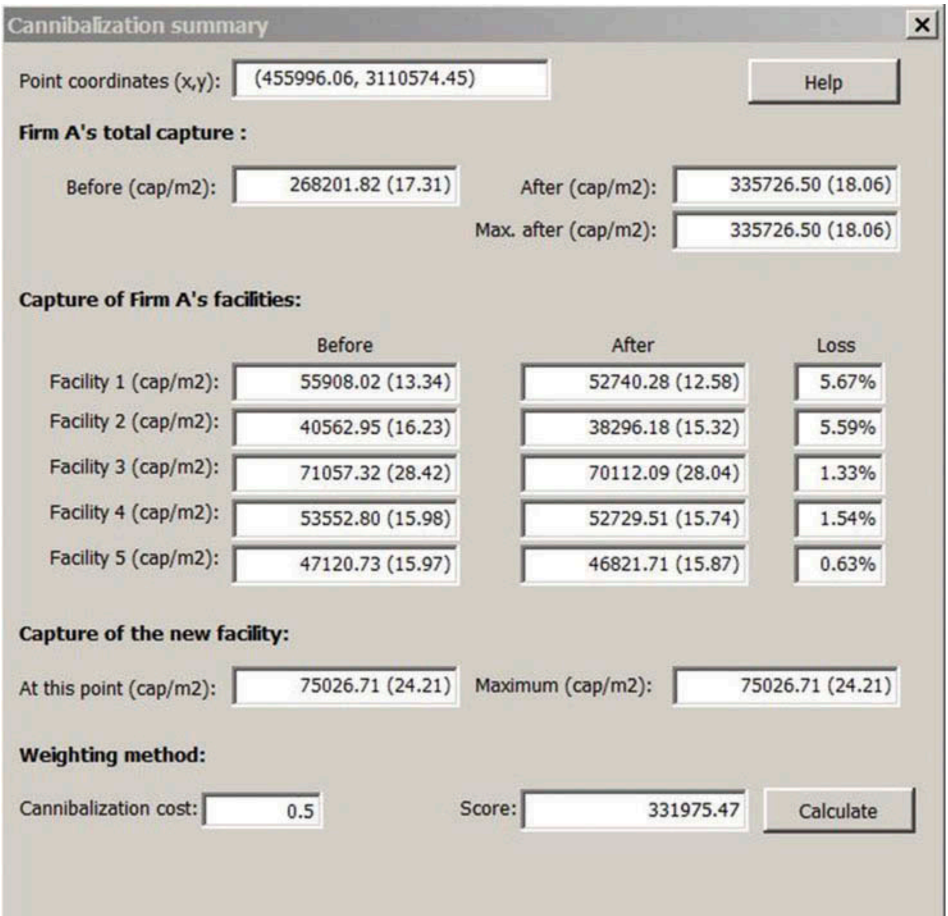

Figure 6. Summary window that appears by clicking on the site labeled as Location 1 in Figure 5.

profitability by 0.75 points. If another point was pinpointed, the loss of opportunity with respect to the maximum could be deduced comparing the ratios capture by m^2 appeared in the 'After' and the 'Max. after' windows.

Moreover, besides the capture values before and after the opening of the new facility, the loss of market share (cannibalization) suffered by the existing friendly facilities is displayed. An analysis of the loss data can be very useful in evaluating the individual cannibalization for the existing stores and facilitates the detection of viable sites. For example, if at most 5% cannibalization is allowed, the location that maximizes the total capture must be discarded as a potential site for the new hypermarket. If cannibalization thresholds higher than 5.67% are allowed, this location is the solution obtained when the multi-objective problem is solved using the constraint method.

In the section 'Capture of the new facility', the summary window shows the capture of a new facility located at the analyzed point and, on the right hand side, the maximum capture that a new facility can obtain in the feasible region if this facility operates individually, that is, the optimal value of $MSN(x)$ (defined in (6)) in the feasible set. For this example, the location that maximizes chain A's total capture coincides with the location that maximizes the new store capture. Furthermore, the results evidence that the new store has a very high ratio of captures per sales surface (only comparable with that obtained by facility A3). Finally, the last section of the window shows the score (goodness index) for the analyzed point. This cannibalization cost can be changed directly in the window and the corresponding score can be obtained by clicking on the Calculate bottom.

This GIS tool allows the analyst to incorporate additional conditions associated with the location of the new hypermarket. For example, if chain *A* applies a high-protectionist policy to the existing hypermarkets, all the zones where cannibalization is higher than a prefixed percentage of its initial market share can be discarded. So, if a maximum cannibalization level of 5% is imposed, Location 1 would not be feasible for locating the new store. Alternatively, the chain can impose a minimum market share requirement (with or without taking cannibalization into account explicitly) for locating the new hypermarket. The solutions may be different in these two situations.

In order to analyze the effect of varying the parameter values on the solution to the location problem, the previous scenario (S1) has been modified by changing the size for the new store (scenarios S2 and S3) as well as varying the speeds associated to the different types of roads (scenarios S4, S5, and S6). The minimum and maximum sales surface for the existing chain A's facilities were allocated to scenarios S2 and S3, respectively, and speeds for the different types of roads for scenarios S4, S5, and S6 were randomly chosen in the intervals [30, 50], [50, 60], [60, 70], [70, 80], and [80, 120]. For each of these scenarios, the weighting method was applied considering cannibalization weights (γ) varying from 0.1 to 11 (with 0.1 incremental steps from 0.1 to 1, and 0.5 incremental steps from 1 to 11). The constraint method was solved varying the percentage of admissible cannibalization (α_i) from 0.1% to 30% (in 0.1 incremental steps).

Table 2 shows the results obtained from the sensitivity analysis. Results from both the weighting and constraint methods reveal two promising areas, Zone 1 and Zone 2. Columns 4 through 7 show the values of the cannibalization weight (γ) and the percentage of admissible cannibalization (α_i) for which Zone 1 is better than Zone 2 and vice versa. Zone 1 is considered better than Zone 2 when the weighting method is applied using the lower cannibalization costs (varying the upper threshold between 7.5 and 10, depending on the scenario), or when the constraints method is used with the higher cannibalization thresholds (for cannibalization levels higher than or equal to 4% or 5% of initial market share, depending on the scenario). Zone 2 is the most promising when a very high cannibalization cost (weighting method) or a very low cannibalization threshold (constraint method), is considered. Note that, for the constraint method, when the cannibalization threshold is 0.1%, no feasible solution exists in either of the scenarios.

Table 2. Sensitivity analysis for the two multi-objective optimization methods.

Scenarios			Weighting method (γ)		Constraint method (α_i)	
Label	Speeds	Size (m^2)	Zone 1	Zone 2	Zone 1	Zone 2
S1	40-60-70-80-120	3099	0.1–9	9.5–11	5–30	2–4
S2	40-60-70-80-120	2500	0.1–10	10.5–11	4–30	2–3
S3	40-60-70-80-120	4191	0.1–8	8.5–11	5–30	2–4
S4	37-56-65-78-80	3099	0.1–7.5	8–11	5–30	2–4
S5	42-60-69-75-119	3099	0.1–10	10.5–11	5–30	2–4
S6	34-59-64-80-107	3099	0.1–9	9.5–11	5–30	2–4

4. Conclusions

When a chain (firm *A*) operating in a market seeks to determine the location for a new store, two frequently conflicting objectives are involved: maximization of the total market share captured by the firm and minimization of market share loss of its existing facilities due to being captured by the new firm. We consider a market as a situation where several stores (some belonging to firm *A* and some belonging to others, designated as firm *B*) are operating to serve the existing demand, which is assumed to be aggregated in a finite set of points.

The problem is formulated as a multi-objective competitive location model for which two resolution techniques are applied, the weighting and the constraints methods. This model is integrated in a GIS framework which was developed to analyze the market situation both before and after the entry of a new facility. Given the quality level (for instance, the size) of the new store, the market share maps (both for chain *A* and for the new facility) and the cannibalization maps are obtained. From these maps, decision-makers obtain not only the locations which optimize each of the objectives that they represent, but also a broad view of the profitability of the different sites belonging to the feasible region.

The multi-objective optimization methods have been implemented in a GIS approach using standard spatial tools over the market share and cannibalization maps. These methods have been applied to analyze real data problem considering different scenarios. The conclusions of both methods coincide in promoting two different zones depending on the importance that chain managers give to the cannibalization effect.

A simple ArcGis tool was developed to summarize the results obtained. By clicking on a feasible point, information about captures and cannibalization are shown. The goodness index for different cannibalization costs can also be calculated. These tools offer detailed and useful information in determining suitable candidate facility locations.

Using GIS allows the incorporation of different restrictions to the feasible region, for instance, the elimination of forbidden areas or the imposition of maximum cannibalization thresholds. Another advantage of using maps for representing the different objectives analyzed in this article is that they can be employed in a multi-criteria environment, as proposed by Suárez-Vega *et al*. (2011), where the objective of maximizing the demand captured by the new facility is combined with other criteria related to different attributes, such as the distance to trade ports, the distance to main roads, the concordance of land use with commercial activity, and the slope of the terrain.

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References

Ballestero, E. and Romero, C., 1998. *Multiple criteria decision making and its applications to economic problems.* Boston, MA: Kluwer Academic Publishers.

Berman, O., Drezner, Z., and Krass, D., 2010. Generalized coverage: new developments in covering location models. *Computers & Operations Research*, 37, 1675–1687.

Berman, O., Krass, D., and Drezner, Z., 2003. The gradual covering decay location problem on a network. *European Journal of Operational Research*, 151, 474–480.

Church, R.L., 2002. Geographical information systems and location science. *Computers and Operations Research*, 29, 541–562.

Current, J.R. and Storbeck, J.E., 1994. A multiobjective approach to design franchise outlet networks. *Journal of the Operational Research Society*, 45, 71–81.

Devletoglou, N.E., 1965. A dissenting view of duopoly and spatial competition. *Economica*, 32 (126), 141–160.
Devletoglou, N.E. and Demetriou, P.A., 1967. Choice and threshold, a further experiment in spatial duopoly. *Economica*, 34 (136), 351–371.
Drezner, T., 2010. Cannibalization in a competitive environment. *International Regional Science Review*, 34 (3), 306–322.
Eiselt, H.A. and Laporte, G., 1989. Competitive spatial models. *European Journal of Operational Research*, 39 (3), 231–242.
Eiselt, H.A. and Laporte, G., 1997. Sequential location problems. *European Journal of Operational Research*, 96 (2), 217–231.
Eiselt, H.A., Laporte, G., and Thisse, J.F., 1993. Competitive location models, a framework and bibliography. *Transportation Science*, 27 (1), 44–54.
Fernández, J., *et al*., 2007. Planar location and design of a new facility with inner and outer competition: an interval lexicographical-like solution procedure. *Network and Spatial Economics*, 7, 19–44.
Friesz, T.L., Miller, T., and Tobin, R.L., 1988. Competitive network facility location models: a survey. *Papers of the Regional Science Association*, 65, 47–57.
Ghosh, A. and Craig, C.S., 1991. FRANSYS, A franchise distribution system location model. *Journal of Retailing*, 67 (4), 466–495.
Hakimi, S.L., 1990. Location with spatial interactions, competitive locations. *In*: P.B. Mirchandani and R.L. Francis, eds. *Discrete location theory*. New York: Wiley, 439–478.
Huff, D.L., 1964. Defining and estimating a trading area. *Journal of Marketing*, 28, 34–38.
Kress, D. and Pesch, E., 2012. Sequential competitive location on networks. *European Journal of Operational Research*, 217, 483–499.
Miettinen, K.M., 1999. *Nonlinear multiobjective optimization*. Boston, MA: Kluwer Academic Publishers.
Murray, A.T., 2010. Advances in location modeling, GIS linkages and contributions. *Journal of Geographic Systems*, 12, 335–354.
Pelegrín, B., *et al*., 2012. On the location of new facilities for chain expansion under delivered pricing. *Omega*, 40, 149–158.
Plastria, F., 2001. Static competitive facility location, an overview of optimization approaches. *European Journal of Operational Research*, 129, 461–470.
Plastria, F., 2005. Avoiding cannibalisation and/or competitor reaction in planar single facility location. *Journal of the Operations Research Society of Japan*, 48 (2), 148–157.
Spaulding, B.D. and Cromley, R.G., 2007. Integrating the maximum capture problem into GIS framework. *Journal of Geographical Systems*, 9 (3), 267–288.
Suárez-Vega, R., *et al*., 2011. A multi-criteria GIS-based procedure to solve a network competitive location problem. *Applied Geography*, 31 (1), 282–291.
Suárez-Vega, R., Santos-Peñate, D.R., and Dorta-González, P., 2012. Location models and GIS tools for retail site location. *Applied Geography*, 35 (4), 12–22.
Zadeh, L.A., 1963. Optimality and non-scalar-valued performance criteria. *IEEE Transactions on Automatic Control*, 8, 59–60.