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Assessing food retail competitors with a multi-criteria GIS-based method

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ABSTRACT: Given the importance of competition in the retail sector, this research builds on spatial interaction theory to develop the competition index (CI). For this, geographic information systems (GIS) and the analytic hierarchy process (AHP) were used. AHP results reveal that key factors to assess competitors relate to location and branding. The proposed method was tested by evaluating 45 supermarkets in the city of Castellón (Spain). Using this method, sales targets can be adapted to each outlet's individual circumstances.

KEYWORDS: Analytical Hierarchy Process (AHP), benchmarking among supermarket, Geographic Information Systems (GIS), multi-criteria decision, geocompetitors.

Evaluación de los competidores de la distribución agroalimentaria con un método multicriterio basado en SIG

RESUMEN: Dada la importancia de la competencia en el sector de la distribución comercial, esta investigación desarrolla el índice de competencia (IC) a partir de la teoría de la interacción espacial, utilizando los sistemas de información geográfica (SIG) y el proceso de jerarquía analítica (AHP). Los resultados del AHP revelan que los factores clave están relacionados con la ubicación y la marca. La metodología propuesta se aplica en la ciudad de Castellón, valorando 45 supermercados. Utilizando este método, los objetivos de ventas se pueden adaptar a las condiciones particulares de cada establecimiento.

PALABRAS CLAVE: Proceso de Jerarquía Analítica (AHP), evaluación comparativa de supermercados, Sistemas de Información Geográfica (SIG), decisión multicriterio, geocompetidores.

JEL classification/Clasificación JEL: L81, M13, R12.

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1. Introduction

Competition strategy affects business performance and marketing strategy (Cardinali and Bellini, 2014). Therefore, when opening or managing an outlet, retailers must consider the competition. Although the retailing maxim is “location, location, location” outlet location is actually determined by target locations’ sociodemographic profile and competitive environment.

Statistics institutes and databases like ACORN and MOSAIC provide population and sociodemographic data, and databases like the Nielsen database provide data on number of outlets in a town. Nevertheless, this information is limited to a series of lists. After these data have been obtained, it is necessary to evaluate each chain, its sales floor area, and other features that are relevant for consumers (Wang and Bell, 2015). All this information is used not only to determine where to open a new outlet, but also to manage the outlet after its opening. Indeed, according to Clarke (2000), analysis of the competition affects both retailers’ efficiency and consumers’ choice. Therefore, analysing how to evaluate the competition becomes especially important for outlet managers (Harvey, 2000).

The current research builds a method to evaluate the food retail competitors. This method is based on spatial interaction theory. We chose this theory because it has been widely used to predict sales, evaluate location options, design location strategies, estimate trade areas and market shares, measure how new entrants in the market affect competing firms’ market share, and so forth. Therefore, the theory of spatial interaction is one of the most productive theories in retail firm location (Sinha, 2000; Bradlow *et al.*, 2005). To define the method to evaluate the competition, we combined the use of geographic information systems (GIS) (Burrough, 1988) with the analytic hierarchy process (AHP) (Saaty, 1980). The choice of these methods (Jeong *et al.*, 2016) owes to the following motives.

First, GIS are capable of quickly representing huge quantities of information on a map using a geographic coordinate system. Similarly, these spatial analysis tools also make it easier than ever to link diverse data sources and accommodate for uncertainty due to scale and aggregation effects (Longley and Mateos, 2005). The capacity of GIS to rapidly combine huge quantities of varied information on one map means they are used increasingly in decision-making (Rob, 2003; Suárez-Vega *et al.*, 2012). Second, the AHP describes general decision processes by decomposing complex problems into multi-level hierarchical structures of objectives, criteria, subcriteria and alternatives. As Aznar and Caballer (2005) and Roig-Tierno *et al.* (2013a) have reported, the AHP admits the use of qualitative and quantitative information about alternatives because it relies on decision-makers’ value judgments rather than empirical data. The AHP thereby enables decision-making and evaluation (Mesa *et al.*, 2008).

The article has the following structure. In section 2, we review spatial interaction theory and propose our method. In section 3, we propose a process to evaluate the competition. Section 4 presents an example of competition assessment in the city of Castellón de la Plana (Castellón) in Spain using the proposed procedure. We then

discuss managerial implications. Finally, section 5 summarises research conclusions, and suggests future lines of research to extend the current study.

2. Spatial interaction theory

Spatial interaction theory consists of a conceptualisation of consumers' spatial behaviour. This theory's pioneer was Reilly (1931), who developed Reilly's law of retail gravitation. According to this law, two cities attract retail trade from any intermediate city or town in the vicinity of the breaking point, approximately in direct proportion to the populations of the two cities and in inverse proportion to the square of the distances from these two cities to the intermediate town (Reilly, 1931). Reilly's model is usually called gravitational because of its similarity with the law of universal gravitation. Reilly's law of retail gravitation is expressed as follows:

$$\frac{T_a}{T_b} = \frac{P_a}{P_b} \left(\frac{D_b}{D_a} \right)^2 \quad [1]$$

Where:

T_a, T_b = proportional part of the trade (from the intermediate place) attracted by centres A and B.

P_a, P_b = population of centres A and B.

D_a, D_b = distances from A and B to the intermediate place.

This model is deterministic because it establishes that T_a / T_b is exactly the proportional part of trade that switches either from A to B or from B to A. The model represents the first attempt to formally delimit trade areas. These areas are considered to be the zones in which outlets generate their sales (Applebaum and Cohen, 1961; Baray and Cliquet, 2007).

Converse (1949) modified Reilly's model to calculate the point between two competing centres at which the trade area of the two centres is the same. Consequently, the trade area can be established by calculating these points and the union between them. The equation of the "breaking point" states that the dividing line between trade areas of two centres A and B lies at a distance in kilometres from point B equal to:

$$D_b = \frac{D_{ab}}{1 + \sqrt{\frac{P_a}{P_b}}} \quad [2]$$

Where:

D_b = the breaking point between A and B in kilometres from B.

D_{ab} = the distance between two cities A and B.

P_b = the population of city B.

P_a = the population of city A.

Huff (1964) criticised both approaches and offered a new perspective, focusing on the consumer instead of the business. He suggested that the utility of a retail outlet j for consumer i (U_{ij}) depends on the size of the outlet (S_j , in square metres) and the distance between outlet j and consumer i (D_{ij}):

$$U_{ij} = S_j^\alpha D_{ij}^\beta \quad [3]$$

In the previous equation, α and β are parameters that reflect the sensitivity of the consumer to surface area and distance, respectively. Because the utility diminishes as the distance to the retail outlet increases, the parameter β should be negative. As the negative value of β increases, so does the importance of distance when the consumer evaluates the retail outlet.

Huff (1964) used only sales floor area to measure attractiveness. To develop this concept, Stanley and Sewall (1976) used a multi-dimensional scale to incorporate the firm's commercial image into the model and thereby improve the model's predictive capability. Gautschi (1981) incorporated additional measures of accessibility (e.g., transport), again improving the model's predictive capability.

The desire to include multiple measures of outlet attractiveness and accessibility led Nakanishi and Cooper (1974) to define a more generalised spatial interaction model known as a multiplicative competitive interaction (MCI) model. However, these models suffer from a major drawback: Their calibration usually relies on survey data. Weisbrod *et al.* (1984) highlighted the financial cost in obtaining the necessary information for these models owing to the number of questionnaires needed for the analysis to be representative. Drezner and Drezner (2002) showed that secondary data on consumer purchasing power and retail sales could be used in gravitational models to predict sales, yielding similar results to those obtained by survey-based models.

Drawing on our theoretical framework, we propose the competition index (CI) as a means to evaluate different characteristics of outlets. The CI uses the attractiveness of competing outlets and the distances between them. This method is useful to measure competition faced by a certain outlet and to evaluate different strategies to improve their management. Recently, Lichters *et al.* (2017) find the attraction effect to be much stronger when decisions are binding, underlining the effect's usefulness as a marketing tool. We evaluate the competition of outlet i in its trade area with n competitors as follows:

$$CI_i = \frac{\sum_{j=1}^n ((1 - At_j) D_{ij})}{n} \quad [4]$$

Where:

CI_i = value of the competition of outlet i in its trade area (competition index).

At_j = attractiveness of competing outlet j .

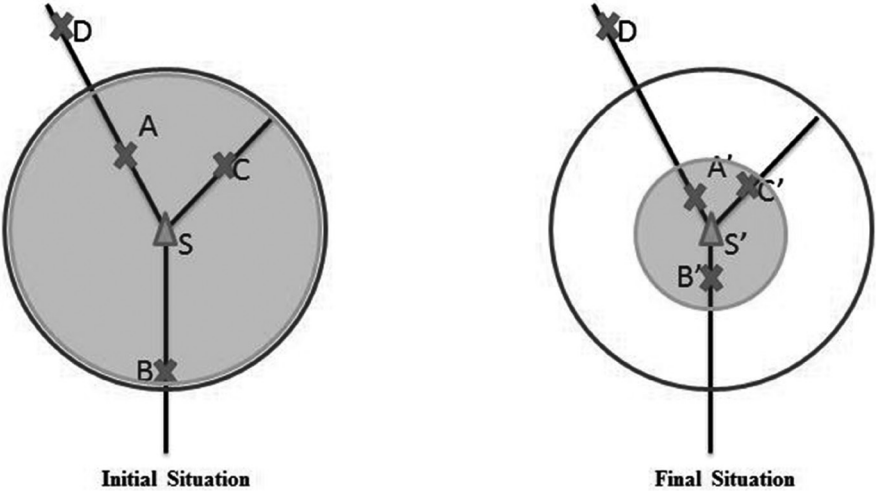
D_{ij} = distance in metres between outlets i and j .

High CI values indicate low competition for outlet i . Our novel contribution to the theory is to use the AHP to measure an outlet's attractiveness (At_j). In doing so, we avoid calibration problems associated with gravitational models. The advantage of the AHP is that it admits the use of qualitative and quantitative variables, while allowing the establishment of criteria and subcriteria. The AHP yields attractiveness as a dimensionless quantity between 0 and 1, which reflects experts' evaluations of a group of variables. The higher the value, the more attractive the outlet is. To measure distances and calculate trade areas, we propose the use of GIS.

The following example illustrates the CI 's foundations. Considering the two situations in Figure 1, we include only supermarkets that lie within the trade area of supermarket S . We therefore exclude supermarket D from the analysis. The CI is thus determined by the average of the attractiveness and distances between all supermarkets in the trade area (A , B and C). Each of these supermarkets has its own attractiveness, being the sum of all of them (A , B , C and S) equal to 1. This attractiveness value affects how close the supermarket gets to supermarket S : When attractiveness is greater, the method places the supermarket closer to supermarket S . The supermarket therefore represents greater competition to supermarket S . Consequently, because attractiveness is dimensionless and the distance is measured in metres, the index determines the distance from supermarket S as a function of the attractiveness of the competition.

For instance, supermarkets A and C in Table 1 lie at an equal distance from S , but because A is more attractive than C is, A would be closer to S than C would be. Because B is the most attractive supermarket, despite being further away than A and C are, B gets very close to S . The average of these values is the CI for supermarket S . In short, high CI values indicate low competition. In other words, high CI values mean that competitors affect supermarket S as if they were located further away from S than they actually are. Therefore, the supermarket will face less competition.

FIGURE 1
Graphical explanation of the competition index



Source: Own elaboration.

TABLE 1
Example of the application of the competition index

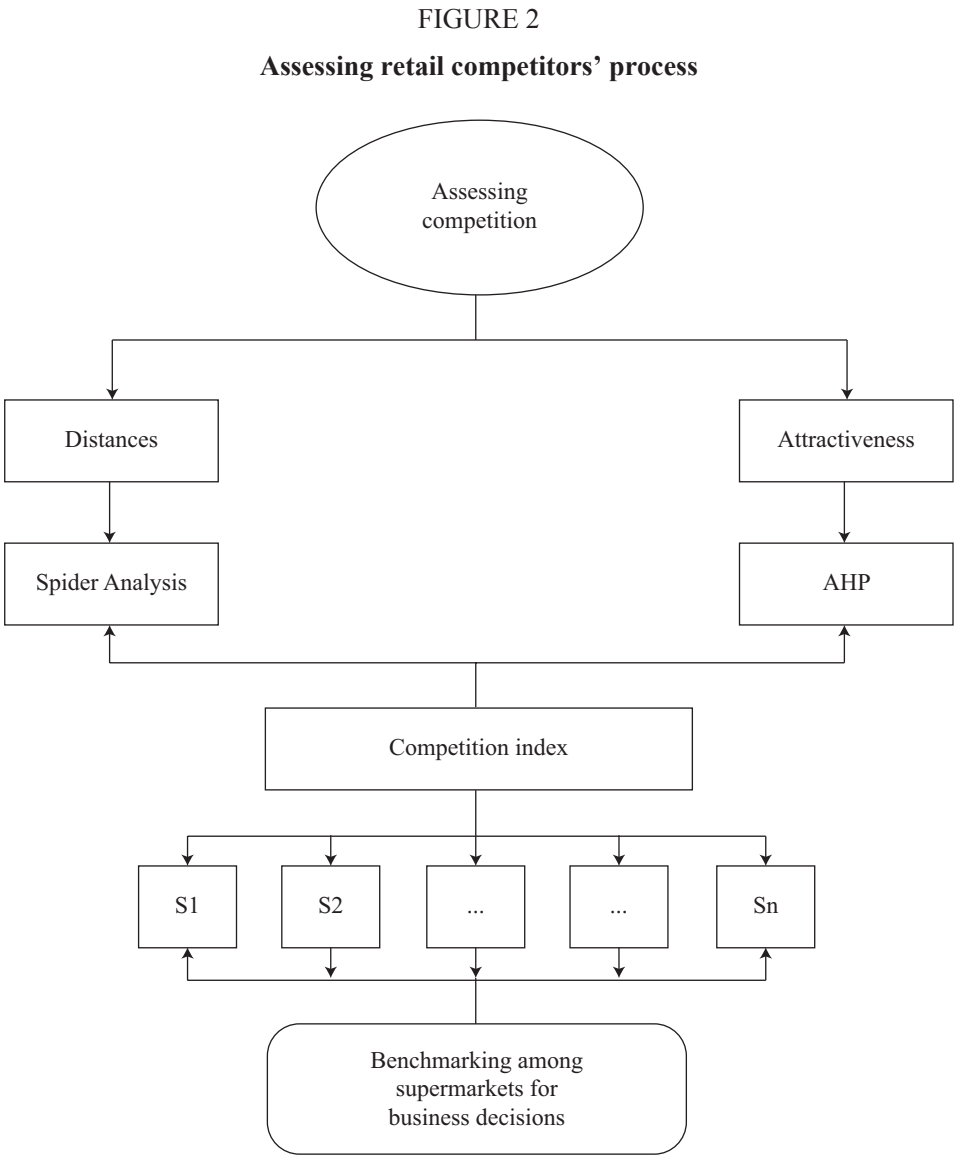
Supermarkets	Attractiveness (At_j)	Distance (D_{ij})	$(1-At_j) D_{ij}$
S	0.19		
A	0.20	150	120.00
B	0.50	250	125.00
C	0.11	150	133.50
Competition index (CI_j)			126.17

Source: Own elaboration.

This methodology used for supermarket S can be repeated for all supermarkets in the same retail chain. The chain can thereby check these indices between all supermarkets (S_1, S_2, \dots, S_n).

3. Assessment of the geocompetitors

The evaluation process of the retail competitors is shown in Figure 2.



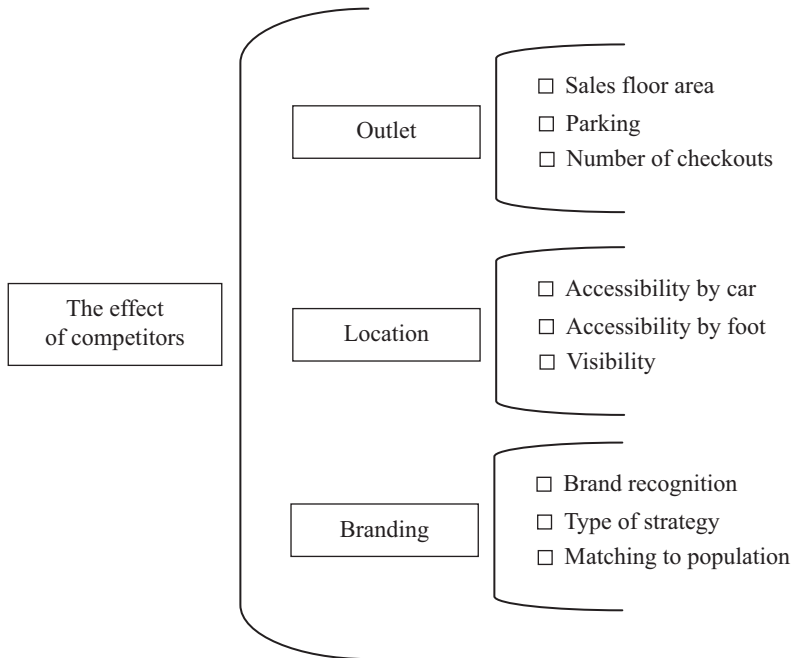
Source: Own elaboration.

The evaluation process of the retail competitors has different steps. First, all supermarkets considered in the analysis were geocodified. The software used in the following steps is ArcGis 10. Geolocation was performed with the *Address Locator* tool found in the *Geocoding* tools. Once the geocompetition had been identified and analysed, the trade area for each of the retail outlets was calculated using the *Network Analyst* tool. The trade area of each supermarket was delimited to identify competing supermarkets. The trade area of each outlet was defined depending on its sales floor area. Sales floor area is a determinant of a supermarket's trade area (Reilly, 1931; Huff, 1964). A sales floor area of 500 m² corresponds to an isochrone of five minutes – equivalent to a radius of 333 m for pedestrian customers. This distance increases as the supermarket's sales floor area increases, and decreases as the sales floor area decreases. If the sales floor area is between 1,000 and 2,500 m², the isochrone is 10 minutes, which equates to a radius of 667 m (Roig-Tierno *et al.*, 2013a). Distances between competing supermarkets within the same trade area were then calculated using spider analysis found in *Spider* tools.

Next, the attractiveness of each supermarket was evaluated using the AHP (Saaty, 1986). First, the decision problem was formulated in a hierarchical structure. The hierarchy (objective–criterion–subcriterion–alternative) meant that elements at the same level were of the same order of magnitude and could interact with some or all elements at the next level. In a typical hierarchy, the highest level is the decision problem or goal. Once the hierarchical model was built, pairwise comparisons between these criteria and alternatives were performed. Thus, experts in the decision process assigned a numerical value (from 1-9) to each criterion according to their preferences (Saaty, 1988).

To establish the hierarchy, we first defined the decision problem or research goal as assessing the effect of retail competitors. To assess the competition, we established three main criteria: outlet, location and branding (Baviera-Puig *et al.*, 2012; Roig-Tierno *et al.*, 2013a; Farber *et al.*, 2014; Verhellen *et al.*, 2016). Each criterion comprises three subcriteria, as shown in Figure 3. The first criterion – outlet – encompasses characteristics of the outlet itself. These characteristics are sales floor area in m² (*sales floor area*), parking facilities (*parking*), and the number of checkouts available to the customer (*number of checkouts*). The second criterion – location – encompasses characteristics relating to the outlet's location. These characteristics are ease of access by car (*accessibility by car*), ease of access by foot (*accessibility by foot*), and distance from which the store is visible and recognisable to potential consumers (*visibility*). The final criterion – branding – encompasses outlets' qualitative characteristics relating to brand. These characteristics are knowledge of the brand in the area (*brand recognition*), commercial strategy employed by the supermarket (*type of strategy*), and the brand's match to the surrounding population (*matching to population*).

FIGURE 3
Factors to assess the effect of the retail competitors



Source: Own elaboration.

Experts evaluated these criteria and subcriteria separately. We then applied scores to different supermarkets (alternatives). Thus, we ranked the competition considering the local conditions of each outlet. Once we had evaluated the competitive environments and characteristics of the supermarket chain's outlets, we obtained a degree of competition for each one.

4. Assessing supermarkets in Castellón (Spain)

4.1. Assessing retail competitors

We carried out our empirical research in the city of Castellón (Spain). Castellón's population was 170,990 on 1 January 2016 (most recent data from the Spanish National Statistics Institute), having dropped by 0.40 % from 2015 (INE, 2017).

We considered 45 outlets from 11 retail firms in the food sector: Eight belonged to supermarket chain S (Consum), and the rest belonged to 10 remaining firms, be-

ing some of them the largest European retailing chains (Aldi, Lidl, DIA, Alcampo, Carrefour, Mercadona, etc.) (Table 2) (Roig-Tierno *et al.*, 2015). We did not consider traditional shops, instead considering only outlets whose sales floor area was greater than 300m² and who belonged to a retail firm. This information came from the Nielsen database (2017).

TABLE 2
Retail outlets in Castellón included in the study

Firm	Number of outlets	Total sales floor area (m ²)	Percentage (%)
Alcampo	1	9,683	15.46
Aldi	3	2,850	4.55
Carrefour	2	10,561	16.86
Consum	8	7,466	11.92
Dia	3	2,296	3.67
Dialprix	4	2,050	3.27
El Corte Inglés	2	2,199	3.51
Lidl	3	2,630	4.20
masymas	3	3,300	5.27
Mercadona	15	19,225	30.70
Suma	1	362	0.58
Total	45	62,622	100.00

Source: Own elaboration.

Seven national experts in marketing provided the study data. We chose experts from a broad range of backgrounds to ensure a range of views and judgments (Wedley *et al.*, 1993). Among the experts, there were academics and professionals who worked in the same supermarket chain. This chain is one of the top five supermarket chains in Spain.

We used a questionnaire to collect data from selected experts. This process allowed us to perform a pairwise assessment of criteria and subcriteria using Saaty's scale (1990). We explained the purpose and content of the questionnaire to each expert in face-to-face individual interviews. Experts then responded to the questionnaire. To merge individual judgments into a single representative judgment for the entire group, we used the geometric mean, as recommended by Saaty (2008). This method maintained the reciprocity property of the trials. In each pairing, an acceptable range for experts' judgments was also established. This avoided inconsistency. The consistency ratio, which can vary depending on the size of the matrix, was used to establish this range. As stated in the literature, the consistency ratio is 0.05 for a 3 × 3 matrix, 0.08 for a 4 × 4 matrix, and 0.1 for all n × n matrices with n ≥ 5 (Saaty,

2000; Cheng and Li, 2001). A consistency ratio value less than or equal to the threshold value implies that the evaluation within the matrix is acceptable and that the matrix represents a good level of consistency in comparative judgments. Conversely, a consistency ratio value greater than the threshold value suggests that comparative judgments are inconsistent and that the evaluation process should be checked. An acceptable consistency ratio helps ensure reliability in the decision-making process.

Once global weights associated with each item had been obtained, subcriteria were ranked (Kallas *et al.*, 2011). According to the experts consulted, the most influential subcriteria in assessing the effect of competitors were matching to population (21.05 %), accessibility by foot (18.55 %), brand recognition (15.92 %), type of competition (11.42 %) and number of checkouts (8.74 %) (Table 3). Grouping these five subcriteria together explained more than 75 % of the assessment of competitors. These results imply that experts perceived the most important factors to be those related to location and branding.

TABLE 3
Ranking of subcriteria that determine the effect of competitors

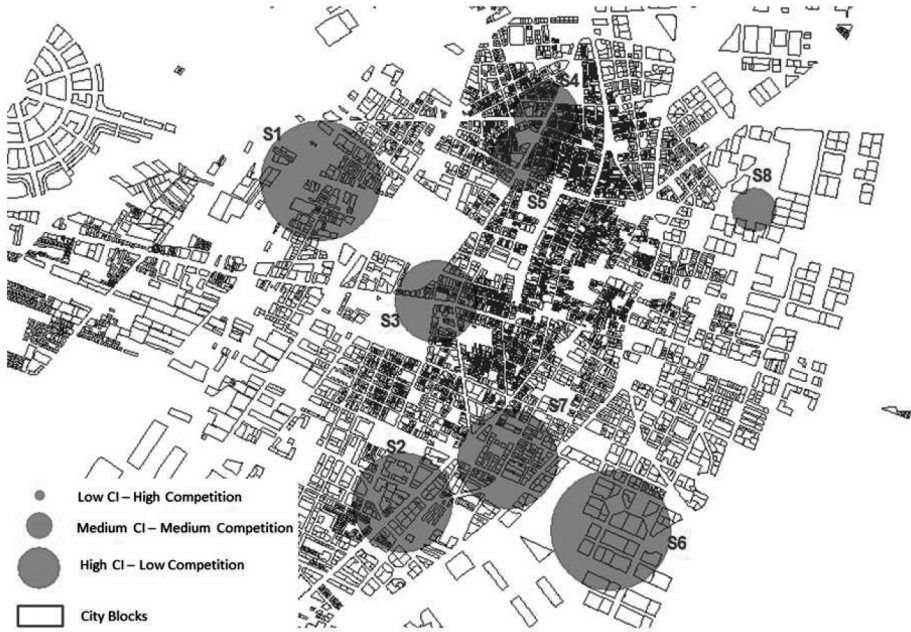
Ranking	Criteria	Subcriteria	Global weight (%)
1	Branding (0.484)	Matching to population (0.435)	21.05
2	Location (0.330)	Accessibility by foot (0.562)	18.55
3	Branding (0.484)	Brand recognition (0.329)	15.92
4	Branding (0.484)	Type of strategy (0.236)	11.42
5	Outlet (0.186)	Number of checkouts (0.470)	8.74
6	Location (0.330)	Accessibility by car (0.252)	8.32
7	Location (0.330)	Visibility (0.186)	6.14
8	Outlet (0.186)	Sales floor area (0.279)	5.19
9	Outlet (0.186)	Parking (0.251)	4.67

Source: Own elaboration.

After defining the weights of the subcriteria, we analysed competing supermarkets in the trade area of outlets S1 to S8 to evaluate the competition each one faced. As with the evaluation of criteria, experts evaluated the competition faced by each of the eight supermarkets to establish the attractiveness of each competing outlet and the outlet S_i . However, whereas the previous process involved administering the questionnaire to each one of the experts and combining the results about the subcriteria, in this process, a single questionnaire was administered to a focus group, forcing the experts to compare their criteria and points of view to provide a definitive common response. We thus obtained the attractiveness of each supermarket. Next,

we applied Spider analysis to calculate the distances between supermarket S_i and the competing outlets within its trade area. Combining this information (attractiveness and distance), we calculated the CI for each of the eight supermarkets S_i . A higher CI indicates greater distance from the competition to supermarket S_i and therefore less competition for the supermarket. A graphical representation of this approach is shown in Figure 4.

FIGURE 4
Graphical representation of the Competition Index



Source: Own elaboration.

We also calculated each supermarket's potential market using GIS and data at the city-block level. Data at this level provide greater detail than data at the census tract level do. We analysed 12,382 city blocks. This procedure is called geodemand and can be defined as digitally mapping the customers of a product or service in a particular market (Roig-Tierno *et al.*, 2013b). Table 4 shows the results of this analysis: CI (m), size or sales floor area (m^2), sales (€), sales per m^2 (€/m 2), population in the trade area (supermarket's potential market) and the average spend per person (€/person).

TABLE 4
Supermarkets' competition index

	CI (m)	Size (m ²)	Sales ^{ab} (€)	Sales/m ² (€/m ²)	Population in trade area	Average spend ^c (€/person)
S ₁	408.25	1,028	3,012,011.37	2,929.97	9,008	334.37
S ₂	355.45	1,325	4,995,061.84	3,769.86	20,172	247.62
S ₃	248.97	764	2,148,492.18	2,812.16	12,863	167.03
S ₄	207.48	608	2,020,668.94	3,323.47	17,665	114.39
S ₅	181.78	950	3,143,274.95	3,308.71	15,753	199.54
S ₆	412.04	1,105	3,605,170.01	3,262.60	10,739	335.71
S ₇	336.53	773	2,069,343.28	2,677.03	16,968	121.96
S ₈	135.21	913	1,569,688.93	1,719.26	10,919	143.76

^a A coefficient to distort real figures was used to avoid publishing actual business data.

^b Coefficient of correlation between CI and sales = 57.5 %.

^c Coefficient of correlation between CI and average spend per person = 74.2 %.

Source: Own elaboration.

The coefficient of correlation between CI and sales for each of the eight supermarkets was 57.5 %. This positive correlation indicates that greater CI implies greater sales. This finding means that higher CI indicates greater distance from the competition to the supermarket and therefore less competition, which results in greater sales. Competition in the trade area explains more than 50 % of sales. The coefficient of correlation between CI and average spend per person (€/person) was 74.2 %. Again, this positive correlation implies that CI explains more than 70 % of a supermarket's sales per person.

4.2. Benchmarking among supermarkets

At this stage, benchmarking techniques between supermarkets can be applied to yield an estimate of targets for each supermarket to increase the firm's overall profit. In general, establishing targets is based on the following premise: If supermarkets with similar competitive characteristics (CI) and market potential (population in the trade area) behave differently, then the firm should instil good practices in underperforming supermarkets and demand that these supermarkets raise their performance to the levels set by their better performing peers.

We took the following steps to establish these targets. First, using the model presented, we calculated the competition index. Thanks to the competition index, we could compare supermarkets. Second, we obtained the number of people in each supermarket's trade area using GIS. Third, we estimated the average spend per customer in the supermarket's trade area. We obtained this estimate by dividing total

annual sales for each supermarket by the number of people in the supermarket's trade area (Table 4). Finally, we estimated average spend as a linear model function, where x represents the supermarket's competition index and y represents average spend per person. This linear model yields an estimate of the average spend in each supermarket. If the estimated average spend is less than the real average spend, it means the supermarket is fulfilling its potential sales. In contrast, if the estimated average spend is greater than the actual average spend, it means the supermarket can increase its sales figures and should therefore change its current business practices.

Table 5 shows that supermarkets S1, S5, S6 and S8 were performing well: Considering the competition and potential market, the real average spend was greater than the estimate was. In this case, their performance was rated as "good". Conversely, supermarkets S2, S3, S4 and S7 were performing more poorly, being rated as "should improve". Each of these supermarkets should aim to make consumers increase their average spend by 1.54 %, 10.85 %, 39.30 % and 96.51 %, respectively. If S2, S3, S4 and S7 improved their performance and met their targets, it would correspond to a profit growth of more than three million euros for the firm in the following year. Specifically, the management should invest more effort in S7 as the difference (in € and in %) is the greatest one.

TABLE 5
Targets by supermarket using the information provided
by the competition index

	Average spend (€/person)	Estimates (€/person)	Difference (€/person)	% difference	Performance
S ₁	334.37	284.30	50.07	14.97	Good
S ₂	247.62	251.44	-3.82	-1.54	Should improve
S ₃	167.03	185.16	-18.13	-10.85	Should improve
S ₄	114.39	159.34	-44.95	-39.30	Should improve
S ₅	199.54	143.35	56.19	28.16	Good
S ₆	335.71	286.66	49.05	14.61	Good
S ₇	121.96	239.66	-117.7	-96.51	Should improve
S ₈	143.76	114.36	29.4	20.45	Good

Source: Own elaboration.

5. Conclusions

Analysing and evaluating the competition is becoming increasingly important for firms when opening new outlets and managing existing outlets (Harvey, 2000). Using GIS and AHP, this research develops a method to evaluate competition in the retail sector. The model and method proposed are low cost because they work

without surveys for calibration. They therefore overcome the limits of Nakanishi and Cooper's (1974) model.

A further advantage of this method is that the AHP admits the use of qualitative and quantitative variables based on expert judgments rather than empirical data. Similarly, the method and the weights of criteria can be extrapolated to all locations and can be used anywhere. One drawback of the AHP is that it limits the number of options within the trade area to a matrix of eight by eight because of the restrictions set by Miller's (1956) magic number. Nevertheless, this limitation actually has little negative effect on results because the distance customers are physically able to walk to reach supermarkets naturally restricts their choice of supermarket. The AHP revealed the most influential subcriteria in assessing competitors' effect: Matching to population (21.05 %), accessibility by foot (18.55 %), brand recognition (15.92 %), type of competition (11.42 %) and number of checkouts (8.74%) explained more than 75 % of the assessment of competitors. These results imply that the key factors when assessing competitors relate to location and branding. Therefore, managers must consider location when deciding where to open an outlet and must consider the importance of promotional activities directed at the target market.

The use of GIS means that managers can take individual managerial decisions for each outlet. This approach benefits large retail firms that need to implement control and performance procedures in their outlets. This study presents a method that can be used to establish real targets for each outlet by considering competitive environments and geolocating demand within the trade area. Thus, the method can be used for benchmarking studies between competing outlets.

We can extend this research to other sectors to verify this method. Because of the high correlation coefficient between CI and sales, future studies should investigate more supermarkets with the dual aim of checking whether the relationship holds or strengthens and developing models that use the CI to predict sales.

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