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USING GIS TO ANALYSE THE IMPACT OF A NEW MOTORWAY IN INDUSTRIAL LOCATION

ABSTRACT: In recent years, the accessibility patterns in Portugal are being changed due to the reformulation of the national road network, particularly with the construction of new motorways. This is the case of the Northwest part of Portugal, where the new motorway A3, between Oporto and Braga, has been introduced in 1991. Because this new infrastructure has increased the accessibility to the sea port and airport of Oporto and to the main transport axes of the country, it seems to be time to a first approach to the study of its impact in the process of industrial location. In this paper a GIS-based model is developed in order to evaluate the impact of a change of accessibility in industrial location. Factors such as the proximity to the population, motorway nodes and urban centres are evaluated and time-spatially referenced in order to detect trends. An application of the model is presented.

1 INTRODUCTION. LOCATION FACTORS

As in any location process, firms consider factors that, from the point of view of their activity, can differentiate the space.

The spatial behaviour of industrial firms has been studied for a long time, mainly through inquiries that identified and sorted the location factors.

The works of Schmenner (1982), Hannoun and Templé (1975) and Stafford (1974) are good examples; for the Portuguese case, the works of Jacinto (1983), Gaspar (1984), Ferrão (1985), L. Caetano (1986), Garrido(1985), Costa and Silva (1994), and Matos (1994) are very important references.

R. Ramos (1996) developed a synthesis where he identifies the following industrial location factors:

- Transport costs and proximity to raw-materials;
- Labour force;
- Proximity to markets;
- Industrial environment;
- Internal communications of firms;
- Land and buildings;
- Infrastructures;
- Service centres;
- Personal factors;
- Local tax conditions;
- Attitude of population in relation to the firm;
- Political support.

Each of these factors has more or less relevance depending on the specific case under study, i.e., the type of industry and the scale of analysis.

The objectives of this paper is to analyse the impact of a new motorway, which is included in the infrastructures factor. Nevertheless, the effect of a raise in the accessibility caused by the opening of the motorway may imply changes in the influence of other factors. Thus, some other factors as relevant as the motorway accessibility, can be selected in order to evaluate the evolution of their relative importance.

Given the aim and scale of this study, the additional major factors selected are: labour force (population), industrial context (presence of a technological pole), and service centres (proximity to major urban centres).

2 FORMAL MODEL

A formal model for impact analysis of a new motorway in industrial location is now presented.

The approach adopted stands on four stages of analysis: (1) Identification of the time periods to be submitted to analysis; (2) Description of the spatial distribution of industrial firms; (3) Identification and description of the concurrent location factors; and (4) Analysis of the influence of the factors.

2.1 Identification of the time periods to be submitted to analysis

Two time periods are considered: before and after the opening of the new motorway.

The extension of the first period should be long enough to allow the analysis of the location pattern before the introduction of the new factor (the motorway). A period of at least five years is acceptable, being guaranteed that during this period there was not a significant change in accessibility, population distribution or industrial context.

The second period should count, obviously, from the opening year of the motorway until the present, or until the introduction of a new factor in the region that could change the attractiveness of the motorway.

2.2 Description of the spatial distribution of industrial firms

To describe the spatial distribution of the industrial firms in the region, a centroid should be calculated for each year of analysis. The data needed for this calculation is a list of the new industrial firms created in each year, usually referenced to the smallest statistical area. In Portugal, these data can be obtained referenced to a subdivision of the municipalities, the so-called Portuguese *freguesias*. These spatial units will be designated in the text by centres, and their point coordinates correspond to the most important population concentration within the zone.

The coordinates of the industrial centroid in year *i* are denoted by X_i and Y_i and given by:

$$X_i = \frac{\sum_j x_{ij} n_{ij}}{\sum_j n_{ij}} \qquad i = 0,1,\ldots$$
$$Y_i = \frac{\sum_j y_{ij} n_{ij}}{\sum_j n_{ij}} \qquad j = 1,\ldots,num_c \tag{1}$$

where x_{ij} and y_{ij} are the coordinates of the centre *j* in year *i*, n_{ij} is the number of new industrial firms created in the centre *j* during year *i* , and num_c is the number of centres.

2.3 Identification and description of the concurrent location factors

As mentioned before, in addition to the accessibility to the motorway it would be interesting to analyse other major factors that concurrently influence the industrial location pattern. The identification and description of a selection of factors is now presented.

Population (labour force)

This factor will be described by a population centroid for each year of analysis. If more than one subregion can be identified (in terms of population distribution) than a centroid should be calculated for each subregion.

Considering that the population data is referenced to the centres mentioned before, the coordinates of the population centroid in year *i* are denoted by X_i^{pop} and Y_i^{pop} and given by:

$$X_i^{pop} = \frac{\sum_j x_{ij} pop_{ij}}{\sum_j pop_{ij}} \qquad i = 0,1,\ldots$$
$$Y_i^{pop} = \frac{\sum_j y_{ij} pop_{ij}}{\sum_j pop_{ij}} \qquad j = 1,\ldots,num_c \tag{2}$$

where pop_{ij} is the resident population of the centre *j* in year *i*.

Usually the population census are undertaken in a 10-year basis (this is the case of Portugal), so it is expectable that statistical population data is not available for each of the years of analysis. In this case it is acceptable to interpolate the population centroid position considering a linear variation during the 10-year census period.

Service Centres

The centres of decision and services to the firms will be described by the coordinates of the corresponding urban centres. Only the relevant centres within the region should be considered.

Motorway

The motorway will be described by the connection nodes to the road network. The coordinates of the centre of the nodes will be considered.

Technological pole

The industrial environment, particularly the existence of technological poles, is a major factor in the industrial location context. It can be described by the coordinates of the poles.

2.4 Analysis of the influence of the factors

The influence of the factors affecting the industrial firms location will be described by the evolution in time of the distance between the industrial centroid and the points that describe the different factors: population centroid, relevant urban centres, motorway nodes, and technological poles.

The distance between the industrial centroid (X_i, Y_i) and the point representing factor $f(X_i^f, Y_i^f)$, in year *i*, is denoted by d_i^f and given by:

$$d_i^f = \sqrt{(X_i - X_i^f)^2 + (Y_i - Y_i^f)^2} \qquad (3)$$

The graphical representation of the distances d_i^f versus time gives a good idea of the evolution of the influence of each factor. Depending on the slope of the line representing the factor, its influence can be increasing (negative slope), decreasing (positive slope) or unchanged (null slope), for a certain period of time, starting from year t (fig. 1).

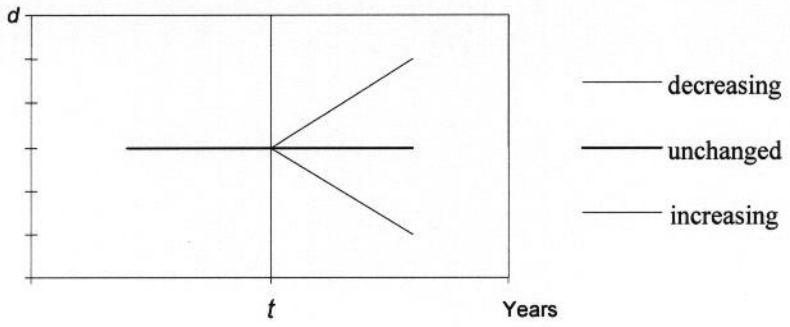

Fig. 1 - Evolution of the influence of a factor

3 APPLICATION

An application of the model developed in the previous section is now presented. The objective is to build a GIS-based tool in order to evaluate and monitor the impact of a new motorway in industrial location in a region of the Northwest of Portugal.

The study area includes the municipalities of Santo Tirso and Vila Nova de Famalicao, with a total area of about 407 km2. The new motorway, designated A3, crosses the area following the North-South direction (Fig. 2).

There are relevant urban centres that supply services to the firms: the cities of Trofa, Santo Tirso and Vila Nova de Famalicao. In the region there is not a single technological pole, so this factor will not be considered in the analysis.

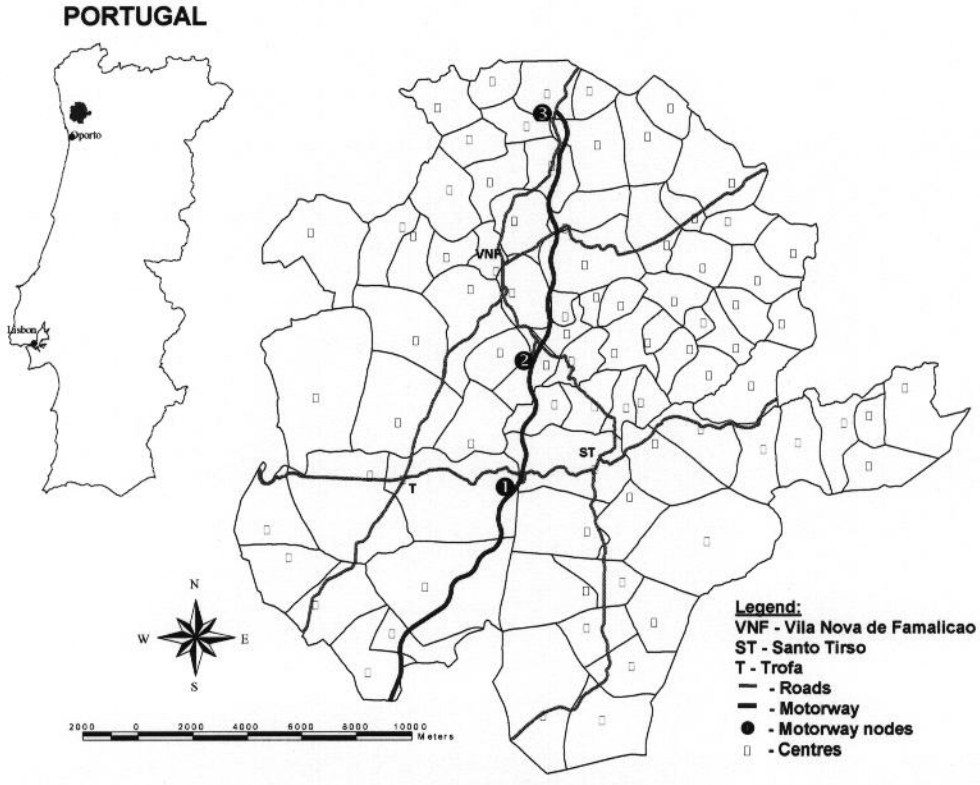

Fig. 2 - Study region

3.1 Time periods considered

Since 1985 there has been a great increase in the creation of new industrial firms (Fig. 3). Considering that the motorway A3 was introduced in 1991, two time periods were considered for analysis: the first, from 1985 to 1990; the second from 1991 to 1993 (the last year to which there is data available).

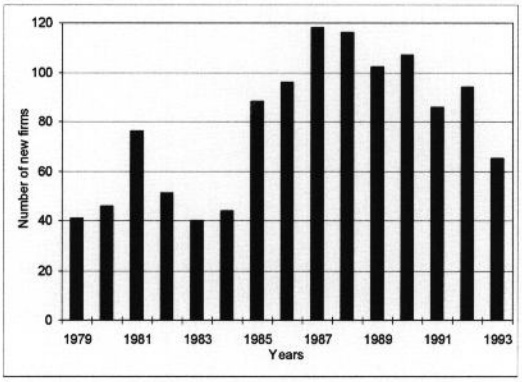

Fig. 3 - Industrial firms created in the period 1979-93

The spatial distribution of the firms created by *freguesia* is represented in Fig. 4 (1985-90 period) and Fig. 5 (1991-93 period). Although the time period is too short to support solid conclusions, it seems that there is a concentration trend around the major urban centres and the motorway node 1.

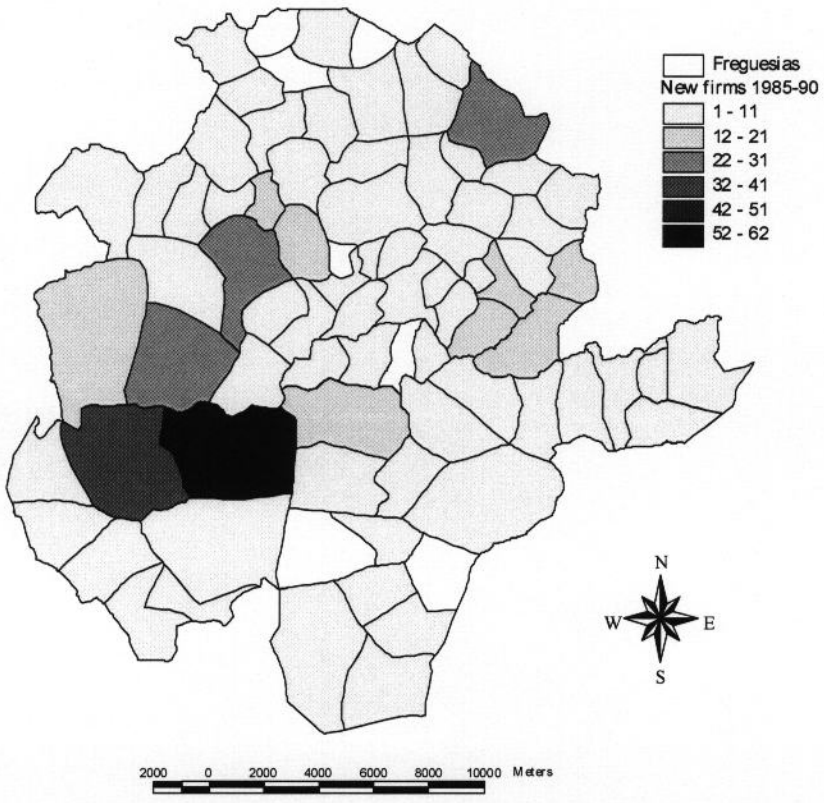

Fig. 4 - Spatial distribution of new firms created in the period 1985-90

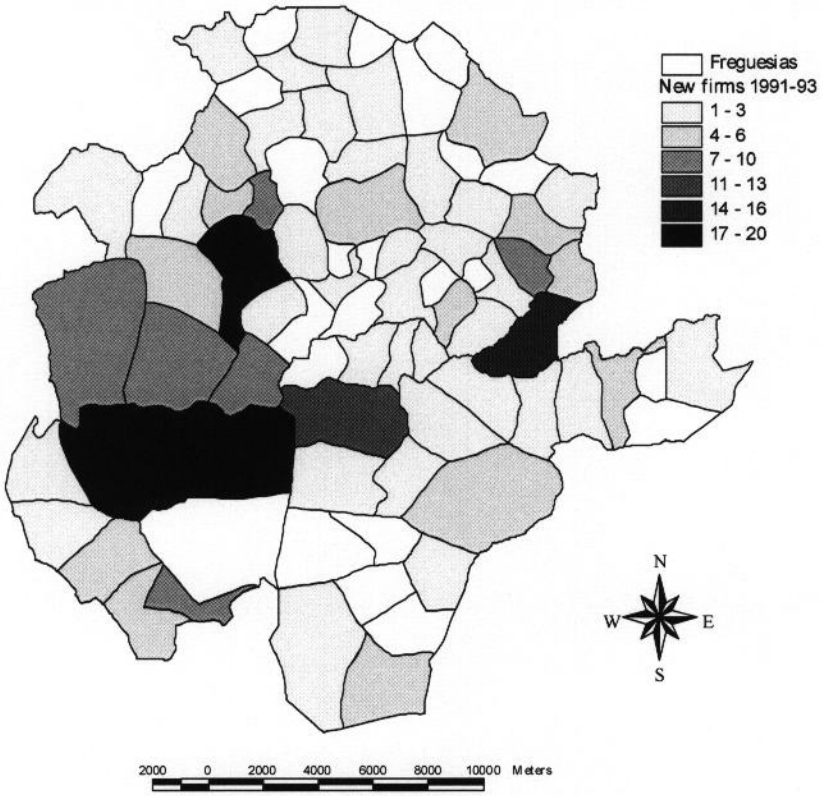

Fig. 5 - Spatial distribution of new firms created in the period 1991-93

3.2 Database themes

Given the model presented, a set of databases needed can be identified:

- resident population by year and by *freguesia*, referenced to a centre;
- limits of the *freguesias*;
- primary road network;
- new motorway A3;
- position (x, y coordinates) of the nodes of the motorway A3;
- position (x, y coordinates) of the urban centres;
- data related to the industrial firms located in the region.
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Table 1 lists the GIS topological database themes developed during the project, using ArcCAD GIS software from ESRI. The conversion process of the 1/25.000 scale hard-copy maps into digital GIS databases was followed by a sequence of three GIS tasks (Mendes, 1995): analogue-to-digital map conversion, topology creation, and attribute assignment.

Table 1 - GIS database themes

GIS themes	Type	Description
Fregues	Polygon	Limits of the *freguesias*
Centros	Point	Location (x, y coordinates) of the centres
En	Line	Primary road network
Ae	Line	New motorway A3
Nos	Point	Location (x, y coordinates) of the motorway A3 nodes
Cen_adm	Point	Location (x, y coordinates) of the service centres
Pop_freg	Record	Population data
Industria	Record	Industrial firms data

3.3 Analysis

Using expression (1), the coordinates of the industrial centroids were calculated for the years of 1985 to 1993 (Table 2).

Table 2 - Coordinates of the industrial centroids

Year	X (m)	Y (m)
1985	17916	9927
1986	18096	10130
1987	17215	9509
1988	17995	9405
1989	17988	9458
1990	18485	9521
1991	17565	9550
1992	17405	8541
1993	15644	7543

The evolution of the industrial centroid can be observed in Fig. 6, where the points representing the factors are presented as well. It is obvious that, after 1991, the centroid moves to the south, and is closer to the motorway node 1.

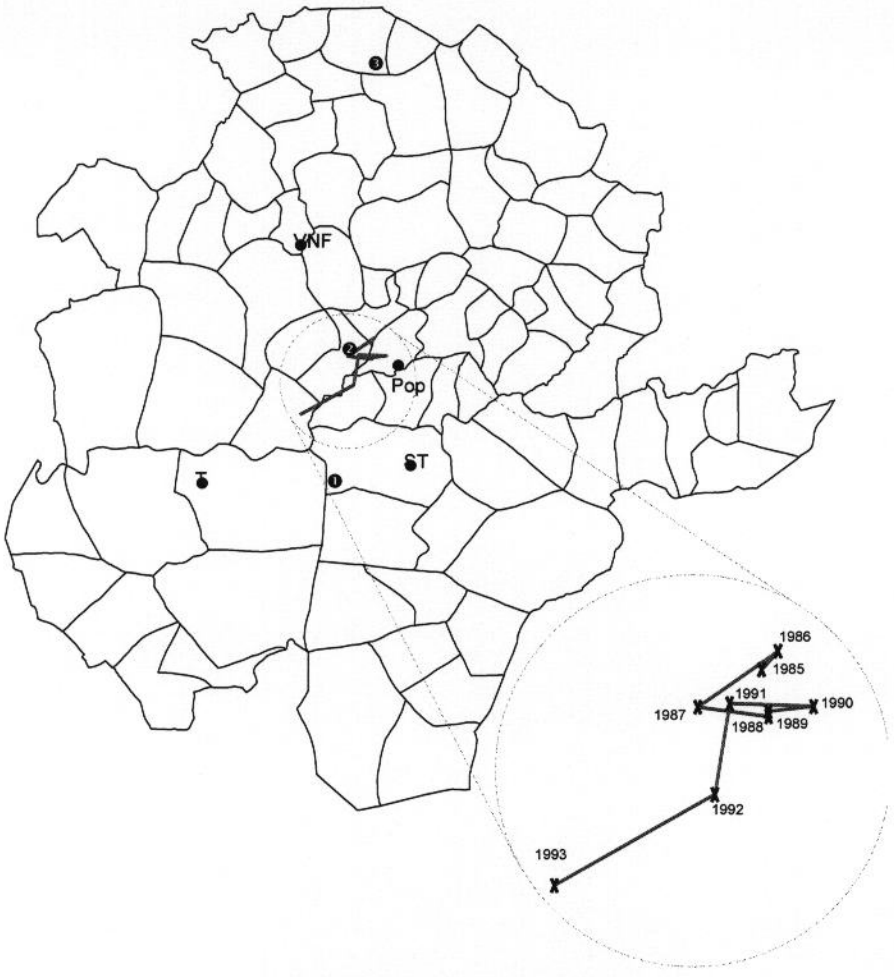

Fig. 6 - Evolution of the industrial centroid

For each of the major factors, the coordinates of the associated points were calculated, or measured (Table 3). These spatial calculation/measurements were performed using the implemented model within the GIS environment.

Table 3 - Coordinates of the points describing the major location factors

Factor	X (m)	Y (m)
Population (labour force)	18724	9256
Vila Nova de Famalicao	15679	13247
Santo Tirso	19318	5843
Trofa	12234	5462
Node 1 (South)	16520	5287
Node 2 (Centre)	16999	9678
Node 3 (North)	17856	19121

The evolution of the influence of each factor can be analysed in Fig. 7, which represents the distance between the points describing the factors and the industrial centroid, for each year.

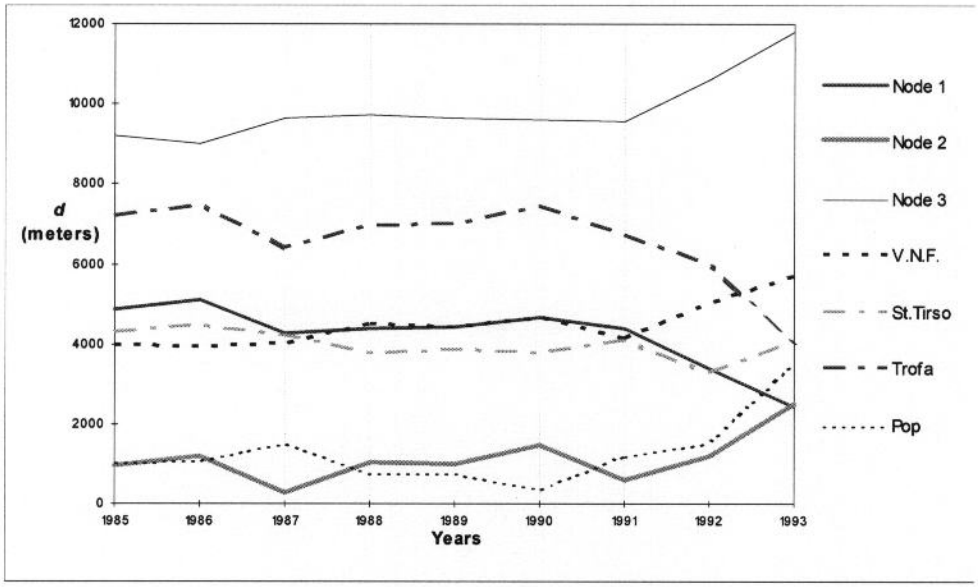

Fig. 7 - Influence of concurrent factors

As a general conclusion, Fig. 7 shows that before 1990-91 there was not great changes in the importance of the factors considered. In relative terms, the most influencing factors for that period were the population (proximity to labour force), followed by the urban centres of Santo Tirso and Vila Nova de Famalicao and, finally, the city of Trofa. It must be stressed that, before 1991, the distance between the industrial centroid and the locations of the motorway nodes are not relevant for the analysis because the motorway did not exist.

After 1990-91, with the introduction of the motorway, there has been a significant change in the spatial behaviour of the firms. As Fig. 7 shows, three situations can be identified:

- the influence of the city of Santo Tirso remains approximately unchanged;
- the influence of nodes 2 and 3, the cities of Vila Nova de Famalicao, and the population centroid is decreasing;
- the influence of node 1 and the city of Trofa is increasing.

A final comment to stress that the analysis period is still short (only three years after the opening of the motorway) to support a solid conclusion on the location trends of the study area.

5 Conclusion

A model to analyse the impact of a new motorway in industrial location was developed within a GIS environment.

Considering that the analysis period after the opening of the motorway is still short, the location behaviour of the firms should be monitored for the next years. The GIS-based model built proved to be useful and will be used as a trend detection tool in the future.

Acknowledgements

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References

Caetano, L. (1986) - *A indústria no distrito de Aveiro - Análise geográfica relativa ao eixo rodoviário principal (ENnº1) entre Malaposta e Albergaria-a-Nova.* Coimbra, Comissão de Coordenação da Região Centro.

Costa, J.S.; Silva, M.R. (1994) - *Modelo empresarial e dinâmica de inovação.* Final Report, Oporto, Oporto Industrial Association.

Ferrão, João (1985) - Alguns elementos acerca das questões de investimento industrial no concelho de Viseu. *Desenvolvimento Regional*, 20, 25-62.

Garrido, Carlos (1985) - Factores de localização das indústrias transformadoras Portuguesas. *Planeamento*, 7(3), 117-125.

Gaspar, Jorge (1984) - *Factores de localização industrial na região centro.* Coimbra, Comissão de Coordenação da Região Centro.

Hannoun, M.; Templé, P. (1975) - *Les facteurs de création et de localisation des nouvelles unités de production.* Institute National de la Statistique et des Etudes Economiques.

Jacinto, R. (1983) - Factores de localização na região do centro - a perspectiva dos empresários. In *Perspectivas do desenvolvimento industrial Português*, Lisboa, APEC, 403-426.

Matos, Elisabeth (1994) - A industrialização nascente em Viseu. *Cadernos de Economia*, VIII(29), 31-38.

Mendes, J.F.G. (1995) - Cost estimation for the conversion of map-based land-use plans into digital GIS databases. *Computers, environment and urban systems*, 19(2), 99-105.

Ramos, R. (1996) - *Localização industrial: uma síntese dos modelos e factores.* Relatório interno. Braga, Universidade do Minho.

Schmenner, R. (1982) - *Making business location decisions*. Prentice Hall.

Stafford, H. (1974) - The anatomy of location decision: Content analysis of case studies. In Hamilton, *Spatial perspectives on industrial organization and decision-making*, J. Willey.