A Decision Support System for the Ecological Selection of a Facility Location: A Multi-Criteria Approach

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ABSTRACT
In this article the authors develop a decision support system for the selection of facilities location using a modification of the Brown Gibson model. The decision process of selecting an area in urban and rural environments is using objective factors considered by Gibson model and subjective factors which were determined using empirical data. The selected approach is built around a multi-criteria methodology with reference to objective and subjective criteria, which constitute the quantitative and qualitative parameters of the system, respectively. The model excludes any critical factors that may distort its usefulness, by choosing among pre-selected areas that fulfil certain minimum pre-requirements. Research findings provide useful indications that can improve the body of knowledge of location-theory. In addition, they can contribute to the development of policy proposals for the Greek state regarding the issues of: selection of location and residence, regional development, decentralisation as well as the study of the non-homogeneous and in-balanced development of areas in urban and rural environments.

Keywords: Brown-Gibson, location, multi-criteria, urban, rural

1. INTRODUCTION
Decisions on site investments are usually based on a number of parameters, with particular hierarchies or combinations of factors considered for particular circumstances. An enormous deal of attention in the literature has been given to optimal location factors in industrial location decision (Jungthrapanich and Benjamin, 1995), but not so much in residential location. It would not be wrong to say that not every factor in the literature is appropriate for every industry or location. Moreover, these factors are likely to differ over time, type of business or area specific features.

To date, in the literature, there has not been a well-defined linkage between all these factors and location selection. In addition, most research do not investigate whether all these factors are still recognised and well documented in practice or not. The intent of this study is to develop a multi criteria evaluation method for area selection in rural and urban environments. Its specific objectives are to:

- review previous models and identify their strengths and weaknesses;
- investigate dominating factors for people or companies deciding to locate their residence or office, respectively, using particular geographical areas with emphasis on rural and urban environments;
- develop a new model that overcomes the weaknesses of the previous models by combining all the necessary subjective and objective factors that influence area selection;
- provide a more efficient and effective framework on which to base decisions;
- apply the model to an example decision involving the selection of two facilities

Its strength is that for the first time all subjective criteria are not determined with the aid of subjective quantification techniques or assigned from personal preferences but their estimation is based on a large scale questionnaire. The model excludes, the use of critical factors, as it considers that choosing an area for residence means that certain minimum (or critical) requirements are already well fulfilled by these areas.

The article starts with a list of quantitative and qualitative factors that influence area selection. It tries to identify the optimal location factors that fit most advantageously with the residence internal environment. Then the model is developed based on Brown-Gibson's work and with reference to the selected optimal location factors. In section 3, an application of the model is conducted, through a five step process, by selecting two residential sites, one in urban and another one in rural (natural) environment with the objective in mind to determine which site offers the best environment for residence. Finally, in section 4, conclusions are highlighted.

2. DEVELOPMENT OF THEORETICAL MODEL
Although location decisions have theoretically developed quite well for a long time now, an analysis of the literature shows that there still exists a gap between theory and practice, particularly with respect to the residential location question. The approaches summoned in location theory are found to be narrowed in application in actual decisions from the fact that they involve a large number of qualitative and quantitative factors (Juthrapanich and Benjamin, 1995; Badri et al, 1995; Atthirawong and MacCarthy, 2001).

Past research on location decisions often deals with a single objective; while the criteria involved in proposed models are mainly related to cost or to dimensions that are translated into numerical values. However, location selection is a multiple criteria decision making analysis (MCDM) by nature, as the decisions depend on a number of factors (Yang and Lee, 1997). Therefore, there is a need to expand the methods used in order to take into consideration a broad range of factors including objective and subjective aspects. (Keen and Scott-Morton, 1978; Roy and Vincke, 1981; Jacquet-Lagreze and Shakun, 1984; Roy 1988; Zopounidis, 1990, 1995a, 1995b; Hurson and Zopounidis, 1995).

There are four basic categories that deal with the problems of the above nature (Siskos, 1984): (a) multi-criteria mathematical programming, (b) theory of multi-criteria usefulness, (c) theory of superiority relations, and (d) theory of multi-criteria monotonous regression. However, the most common methods in selecting residence sites among alternative solutions are the Electre method (Huylenbroeck, 1995; Dias and Mousseau, 2006), the Promethee method (De Keyser and Peeters, 1996; Le Téno and Mareschal, 1998, Macharis et al, 2004) and the Analytical Hierarchical Process –AHP (Saaty, 1986, 2000), which has been found to be an effective and practical approach that can consider complex and unstructured decisions (Partovi, 1994). For example, the AHP method was adopted for the location and development of a hospital unit according to the following four steps: a) hierarchical definition of building goals, characteristics and criteria, b) collection of data and comparison by pairs based on selection priorities, c) use of the eigenvector method for the hierarchy of decisions, d) synthesis of priorities in general axis and rating of alternative decisions (Sinuany et al, 1995). The same method has been used for the selection of the location area of a restaurant unit in Taipei (Tzeng et al, 2002). In that problem five main characteristics are involved: transport, site, marketability, financial factors, competition and environment, and eleven criteria such as cost of rent, delivery cost, transportation network, parking places, number of passing-by persons, number of competitors, intensity of competition, size of the commercial area, infrastructure of the area, refuse disposal and sewage capacity.

According to Kahraman et al (2003), the selection of residence site is generally regarded as multi- multiple criteria decision making problem that involves quantitative and qualitative criteria and it is not advisable to use conventional methods (Kioxos et al, 2002). Chau et al, (2000) asses the cost effectiveness of an environmental assessment scheme based on economic benefit-cost ratios developed for various criteria. However, such approaches of the cost-benefit nature require that all factors have to be expressed in monetary values, which may lead to wrong conclusions due to: (a) possible errors that occur from the estimation of the monetary flow under uncertainty conditions (existence of probability of alternative values in the future monetary flows), (b) the expected inflation rate (Kyriazopoulos, 2002) and (c) the difficulty in quantifying and eventually use of the qualitative factors through the use of multidimensional statistical models (Srinivasan and Kim, 1988).

For our purpose, the Brown-Gibson model (Brown and Gibson, 1972; Lipovatz-Kremezi, 2003) has been selected. It is a technique for integrating qualitative and quantitative criteria in decision making. We utilize the Brown-Gibson model to cope with both the objective and subjective parameters of the system which describe the ecological behavior of buildings with respect to multiple criteria. We first define the objective criteria for each site (urban and rural) based on the total costs. Then, define the subjective criteria and establish its value. Identify the weighting coefficients pertaining to the importance/weight of the objective and subjective criteria. Finally, calculate the total priority grade for each site (urban and rural) through the combined objective and subjective criteria. Both the weighting coefficients and the priority order of each site regarding each criterion have been found through a survey, based on a questionnaire developed for this purpose. The questionnaire was administered to a number of students' families from academic institutions all over Greece. Based on the above, the site that concentrates the highest grade is selected and the final conclusions are extracted

As an assumption, we accept that the examined buildings are of similar characteristics in terms of properties, mechanical systems, construction materials, etc that can be defined accurately. This will eliminate any biased in air quality (Djukanovic et al, 2002; Tse et al, 2004), thermal or acoustical comfort, so any differences will be contributed to the urban or rural environment rather than the different building characteristics. However, any technical interventions or possible new installations that will be required to improve indoor air quality and/or thermal and acoustical comfort - so that the final measurements will be inside the allowable limits - will be parameterized.

3. THE AREA SELECTION MODEL

One of the most challenging activities deals with the process of matching the organization with its environment in the most beneficial way. This means selecting the external environment itself, via a selection process, to fit the organization.

The area selection model uses several strategic factors to fit the residence with the specific area that best meets its requirements and needs. It has two stages. The purpose of stage one is to determine what factors an area should have to fit most advantageously with the residence internal environment. These factors are referred to as the area Optimal Location Factors (OLFs). The purpose of stage two of the model is to develop the model itself based upon a combination of the Optimal Location Factors (OLFs).

3.1 Determination of Optimal Location Factors

The area selection model recognises the need of some Optimal Location Factors (OLFs) which are identified as belonging to the following two categories: (1) the subjective factors (AK_i) and (2) the objective factors (YK_i).

The *first category*, subjective factors, is characterised by qualitative type criteria such as quality of education, quality of healthcare, quality of entertainment and recreation, quality of natural and material goods, accessibility and availability of transportation, potential growth of the area and employment conditions, pollution problems and ecosystem, crime rate-security, traffic problems-parking areas, companionship-solidarity-sociality. The nature of these factors is of qualitative character as they cannot be given monetary values.

The *second category*, objective factors, is characterised by quantitative type criteria including amongst others, construction cost, cost of preventing pollution, cost for thermal comfort and acoustical comfort, energy cost, and residence cost

A possible third category could also be included, named critical factors. A location factor is considered as critical if it prevents the location of a residence at a specific area despite of the other, possible preferred conditions that occur. For example, an area that lacks schools could not be considered as a potential site for residence in spite of the other subjective or objective factors that may be attractive. In other words, there can not be any trade-off with respect to these factors

3.2 Model Formulation

A modified Brown-Gibson's method was used where for each site i, a location measure, called "total priority mark, B_i" is calculated (Brown and Gibson, 1972; Lipovatz-Kremezi, 2003), based on:

$$B_i = n(AK_i) + (1-n)K_i \tag{1}$$

Where:

ν is the objective factor decision weight with values $0 \le \nu \le 1$

AK_i is the objective factor measure for area i with values $0 \le AK_i \le 1$ and

$$\sum_i AK_i = AK_{urban} + AK_{rural} = 1$$

AK_{urban} is the objective factor measure for urban environment i

AK_{rural} is the objective factor measure for rural environment i.

YK_i is the subjective factor measure for residence i with values $0 \le YK_i \le 1$, and

$$\sum_i K_i = K_{urban} + K_{rural} = 1$$

YK_{urban} is the subjective factor measure for urban environment i

YK_{rural} is the subjective factor measure for rural environment i.

The development of the model was based on the following three assumptions:

Assumption 1 (Critical Factors):

There already has been made a pre-selection of specific areas that fulfil certain minimum pre-requirements and this minimizes the usefulness of the critical factors. Therefore the only optimal Location Factors (OLFs) that will be used are the subjective and objective factors. At this stage, one should appreciate the importance of critical factor, because their inclusion may even exclude an area from considering it, as it doesn't fulfills the minimum requirements imposed by them.

Assumption 2 (Objective Factors, AK_i)

Basically all objective factors are measured in monetary units. However, for the sake of the model, they all are converted into dimensionless indices. Therefore, the objective factor measure Ak_i for area i is determined mathematically by the expression:

$$Ak_i = \left[c_i \sum \frac{1}{c_i} \right]^{-1} \tag{2}$$

where c_i is the total objectivity factor cost for area i.

There are three restrictions imposed by formulae [2]

a. the area with the minimum cost must have the maximum measure
b. the relationship of the total objective factor, AK_i, for each area as compared to all other areas must be preserved, and
c. the sum of the objective factor measures must equal one, i.e. $\sum_i AK_i = AK_{urban} + AK_{rural} = 1$

Assumption 3 (Subjective Factors, YK_i)
All subjective factors are mathematically expressed for an area i, as:

$$YK_i = \sum_{j=1}^{n} W_j R_j \qquad (3)$$

where: W_j is the weight of subjective factor i relative to all subjective factors (pair-comparison), and R_{ij} is the weight of site i relative to all potential sites for subjective criterion j.

Both subjective factor weight, W_j, and site weight, R_{ij}, are determined based on the use of a special questionnaire which has been distributed in a representative sample of students' families. In fact, this is one of the modifications made in Brown-Gibson's method, which determined these two factors with the aid of a subjective quantification technique known as preference theory (Fascal, 1965).

The questionnaire was given to 400 families of students from various Greek educational institutes, with a covering letter explaining the purpose of the survey. The sample was random selected as in the academic institutions the families of the students come from all the social, economic and professional ranks and from all the geographical and administrative areas of the country (urban, semi-urban, rural, etc.), thus having all these demographic, cultural, and other characteristics that makes the sample as representative of the Greek population as possible. The development of the questionnaire was based on three pre-requisites: a) the questions take into account the ability and willingness of the interviewee to participate, b) the answers is short-easy and with a logical sequence and clarity, c) the data processing and the final investigation of the real volition and trend of the sample are feasible.There were 150 replies, which represented 37.5% of the responses. A follow-up of the survey was conducted in July 2006. An additional 54 completed responses were returned, yielding a total of 204 replies, which represented 50.75% of the responses. The pre-test of the questionnaire was conducted with 3 lecturers and 5 students' families in order to ensure that there were no items with multiple interpretations or that were biased, inappropriate or unclear. Furthermore, the measurement items were based on a comprehensive review of relevant literature. Therefore, it can be concluded that the measure developed in this study has content validity.

4. APPLICATION OF THE AREA SELECTION MODEL

To illustrate how the area selection model works, two residential sites have been selected, one in urban environment and another one in rural (natural) environment. The objective was to determine which site offers the best environment for residence.

Patission area which belongs to the municipality of Athens was selected as characteristic urban area, located in a rather small distance from the city centre. It has good accessibility for the provision of goods and services (education, healthcare, recreation areas, markets, etc), the same quality of transport means and infrastructure as Athens, it is highly populated with a wide range of people-income, the cost of living is relatively low, and it has highly environmental (pollution) problems.

For the rural environment, the municipality of Psachna in the Evia island was selected. Psachna is the capital of a small municipality located at a distance of about 16km from the city of Chalkida (the capital of Evia island). Seated at the edge of Dirfis' mountain, it has good quality of transport infrastructure. Being close to the main road connecting Chalkida and Athens makes it quite accessible for the provision of goods and services. Its location characteristics, being next to the mountains in a natural environment makes it a low polluted area, thus fulfilling the minimum requirements and characteristics of the present research.

With the application of the area selection model to the problem of choosing between the above two residential areas, an exercise is carried out below, which briefly contains the following steps.

Step 1
A Table is constructed that shows both the technical data as well as the calculation of the objective criteria expressed by formulae [2]. The aim is to translate each areas objective factors expressed in monetary figures to dimensionless information. A total of five selection criteria are used, including: construction cost, cost of technical interventions for improvement of indoor air quality, cost for thermal comfort, cost for acoustical comfort and residence cost

Step 2
Next the preference frequency of each subjective criterion is calculated by processing the data selected with the questionnaires using SPSS-11 software. Then the weighting coefficients, W_j, for each subjective criterion are determined. A total of ten criteria was used, such as quality of education, quality of healthcare, potential growth of the area and employment conditions, pollution problems and ecosystem, quality of entertainment and recreation, crime rate-security, traffic problems-parking areas, companionship-solidarity-sociality, accessibility and availability of transportation, and quality of natural and material goods,

Once this information is identified the next step of the model is to prioritise each area i with respect to each subjective criterion j selected according to the preferences frequency of the interviewees. Finally the value of the subjective criterion (YK_i) for each site i is determined using equation [3] with the pre-condition, that $\sum_{j=1}^{n} YK_j = 1$. This results that $YK_{urban} = 0.548$ and $YK_{rural} = 0.452$.

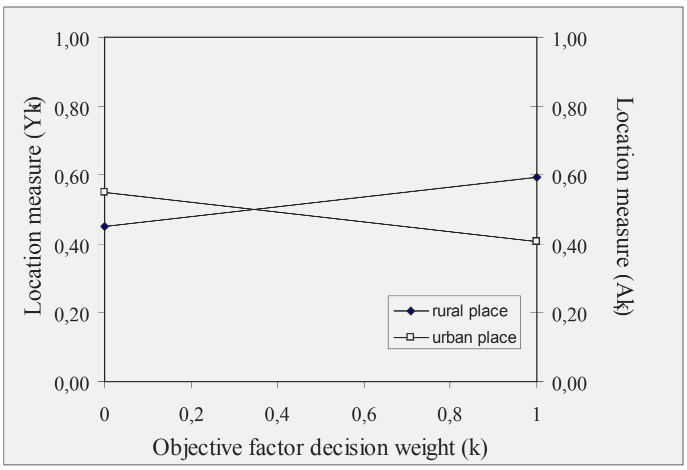
Step 3
The weighting coefficient ν was calculated to be ν=0.415 and 1-ν=0.585. It results from the weighting mean and according to the frequency of appearance of each value. It should be mentioned that the weighting coefficient ν shows the weightiness according to the willingness of the interviewees between objective and subjective criteria.

Step 4
Having calculated, all the independent variables of equation [1] for each site, i, its "total priority mark, B_i" can be estimated but always assuming that $\sum_{i=1}^{n} B_i = 1$. This gives that:

B_{urban}=0.415*0.4052+0.585*0.548=0.4888

B_{rural}=0.415*0.5948+0.585*0,452=0.5112

Figure 1. Sensitivity of location measures to changes in objective factor decision weight, ν



Step 5

Finally a sensitivity analysis is performed to examine the influence of the change in ν value on the final decision, see Figure 1. However, the research is possible to turn to more analytical results regarding the preferences and the selection of the people (regarding e.g. age of gender).

In our specific example, the results of the sensitivity analysis, indicating that for values of $v<0.34$, the urban residence site is preferred; otherwise the rural residence site should be selected.

5. CONCLUSIONS

The selection of a residential site involves the consideration of a large number of quantitative and qualitative criteria that have to be taken into account. Inevitably, this involves multiple and conflicting objectives which although are quite well recognized, their consideration have not been adequately addressed in analysis, yet.

Therefore, one of the most challenging activities is to match the organization with its environment in the most beneficial way, involving all these factors. Its significance has increased recently, due to economic downtimes and the people's environmental consciences. However, existing theories do not provide satisfactory solutions in selecting such sites. One reason for this appears to be the complicated and multidimensional nature of the problem itself. Another reason is that the proposed models suffer from the lack of a procedure that combines objective and subjective factors in an concise manner. Also many of the factors that should be considered in determining the problem cannot confine monetary values thus creating an aching void in location theory.

This article has presented a numerical model for area evaluation. It incorporates a procedure that derives a location measure, for both an urban and rural areas based upon subjective and objective considerations. Moreover, it facilititates sensitivity analyses, thus ascertaining the accuracy of the input data. It offers several advantages over previous models, which among others include:

1. Use of a two-stage model for evaluating alternative quantitative and qualitative factors first, and then evaluating specific areas between the chosen ones. Here the critical factor has not taken into consideration and the sites chosen for comparison have already been pre-selected, so the importance of the critical factors as such is negligible.
2. Incorporates the use of a questionnaire to provide solutions for the selection of subjective criteria, thus deviating from the original Brown-Gibson model which determines these factors with the aid of a subjective quantification technique known as preference theory.
3. Simultaneously considers all decision-making criteria (i.e. subjective and objective factors) to derive an optimal selection.
4. Permits ordinary ranked prioritization of decision-making criteria. For example, the assessment of the subjective criteria shows the following preferences in descending order: quality of the healthcare (17.0 %), quality of education (16.7%), potential growth of the area (13.3%), environmental pollution (12.9%), quality of security and criminality (11.9%) with the rest criteria following with lower percentage.
5. Easy to change objective factor estimates (i.e. model parameters) and solve for a new solution with little effort.

While the model presented in this article provides a powerful decision-making tool for area selection, the information it generates with sensitivity analysis possesses some limitations. One of these is that changes beyond the boundaries defined by sensitivity analysis cannot be interpreted. Such changes can be determined by using the model as a simulation tool. That is, the change can be observed by making a parameter change in the model and resolving the problem to see the simulated effect of the change in the new solution.

There are many other techniques that could be used for location analysis, such as the Analytic Hierarchy Process (AHP) process, but the present method offers some appealing advantages. One of the most important issues of AHP is what criteria should be set as the core evaluation criteria, who will select them and how. This is because using evaluation criteria that are not valued to begin with will risk that the analysis itself becomes meaningless. Another thing is that AHP assumes the system elements are uncorrelated and are unidirectionally influenced by a hierarchical relationship, thus introducing the assumption of independency among the various criteria of decision-making. There is a great deal of subjectivity as the user is asked to subjectively evaluate pairs of attributes on a point scale. However, when it comes to modified Brown-Gibson method, all criteria are set by a large group of people with different demographic characteristics through a questionnaire, thus removing the problems with criteria, hierarchy and subjectivity, as things are seen from different angles

Conclusively, we consider that this article has improved the body of knowledge of location-theory and has aided the decision process involved in residence site selection by guiding management to make better and more objective decisions. This was achieved by modifying and improving the Brown-Gibson's method, where instead of using the preference theory to determine the subjective factors, a questionnaire was designed. This is very importance for the Greek state as it contributes to the development of policy proposals, regional development, and decentralization; while prevents the deteriorate phenomenon that causes the non-homogeneous and in-balanced development of areas in urban and rural environments.

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