ARTICLE IN PRESS

Socio-Economic Planning Sciences xxx (2017) 1–10

Contents lists available at ScienceDirect

Socio-Economic Planning Sciences

journal homepage: www.elsevier.com/locate/seps

A decision model for bank branch site selection: Define branch success and do not deviate

Julia García Cabello*

Dpto. de Matemática Aplicada, Facultad Ciencias Económicas y Empresariales, Universidad de Granada, Spain

ARTICLE INFO

Article history:
Received 14 December 2016
Received in revised form
28 July 2017
Accepted 11 September 2017
Available online xxx

2000 MSC:
C61
C63
G17
G21

Keywords:
Bank branch site selection
Imitate branch success
Feature vector

ABSTRACT

Site selection is one of the most important decision making processes for firms since, if done correctly, it provides access to the best customers and the greatest market potential. In contrast, poor location choices are costly and difficult to reverse.

This paper deals with the single branch site selection problem in the banking context. Due to the high level of complexity (several factors have to be taken into consideration in the decision making process as well as a wide range of entities' internal requirements), to date there is no single procedure that fits all needs. This paper attempts to provide a solution to this problem by proposing a unified method based on minimizing the distance from the candidate-branch to the most successful branches, taking into account each banking institution' notion of branch success. This methodology would work well at the lowest possible cost.

1. Introduction

Site selection is one of the most important decision making processes for firms since, if done correctly, it provides access to the best customers and the greatest market potential. In contrast, poor location choices are costly and difficult to reverse. This also applies to the banking sector, where the problem of finding the best location for branches is of prime importance in order to achieve the objectives set by the banking entity. In the present scenario of a highly competitive banking industry, demographic branch site selection is one of the key factors in maximizing a bank' profitability and increasing its market share (see Fig. 1).

The problem of deciding on the best site for a new branch may be viewed as part of the general problem of restructuring the bank branch network, [11]. Such a need arises in the event of changes in bank regulations, motivating mergers that necessitate a redesign of the branch network. This may also occur in other contingencies such as acquisitions or the entry of a new bank into the market.

In such circumstances, however, it may simply be sufficient to open *single offices* that provide banking facilities for the bank, both permanent and temporary, or to relocate branches or central hubs. This paper deals with this single branch site selection problem in the banking context under the assumption that, to date, there is no one-size-fits-all procedure. As a matter of fact, due to the high level of complexity (several factors have to be taken into consideration in the decision making process as well as a wide range of entities' internal requirements), so far no method of selecting optimal branch sites has yet been developed that applies to all scenarios. This paper attempts to provide a solution to this problem by proposing a procedure that would work well for the greatest possible number of cases for the least possible cost.

In general terms, selecting best location for a new branch means taking into account certain criteria that depend on several (internal and external) factors. Hence, a prior step in the selection of a suitable site involves first identifying the key determinants and then deciding which criteria are to be used in order to select the ones that best fit the needs being considered. As a consequence, branch site selection is a multi-criteria decision making problem for which the selection process usually is multi-stage with different (sub)criteria at each level. To this wide variety of possible criteria may be added the fact that some determinants (demographic and

* Dpto. de Matemática Aplicada, Facultad de C.C.E.E. y Empresariales, Campus de Cartuja, Granada 18071, Spain.
E-mail address: cabello@ugr.es.

http://dx.doi.org/10.1016/j.seps.2017.09.004
0038-0121/

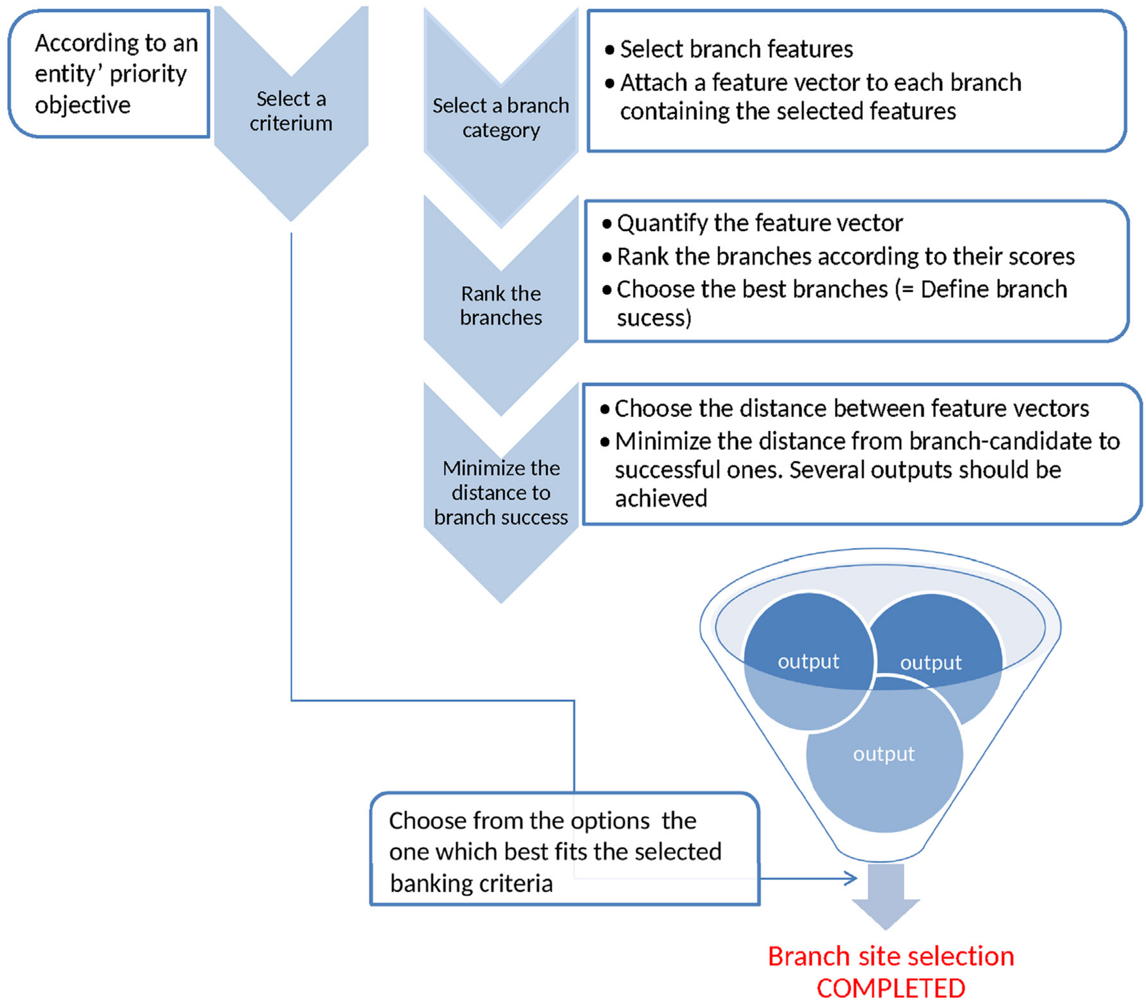

Fig. 1. Branch site selection model.

socioeconomic factors, sectoral distribution of employment, regional trade potential, etc.) have to be carefully managed due to there being major variations in specifying local parameters as opposed to internationally-accepted criteria. This is the case of local demographics, which directly affect one of the main branch features, the *branch size*. In fact, there is a close relationship between branch size and local demographics since branch size depends on branch cash transactions (number and amount) while these depend on branch customers' needs for cash and these, in turn, strongly depend on local demographics.[1] Nevertheless, there is no unified vision related to specifying local demographics due to the major variations in defining particular types of areas: the distinction between urban and rural zones is growing fuzzy because the main criteria defining these commonly include factors such as population size/density, availability of certain support services like secondary schools and hospitals which can vary greatly. Even the thresholds used across countries may differ.

The multi-criteria nature of the problem together with the aforementioned fuzziness of (some of) the key determinants, make it impossible to cover all types of branches from every kind of banking institution with a single model. As a matter of fact, while the literature shows that different criteria as well as different mathematical techniques may be used for handling the problem of bank branch location, it also highlights that there are neither common criteria nor common procedures (see Ref. [6]). The contribution of this paper is, thus, to address a unified vision by taking advantage of *each* particular notion of bank branch success to propos a decision model based on minimizing the distance from the candidate-branch to the most successful branches.

As mentioned, the problem addressed in this work may be included in the literature on bank branch selection under certain pre-fixed criteria. In addition to the full range of factors contributing to branch selection choices, a set of mathematical techniques have also been used. In Ref. [10] a model was developed aimed at planning new branch locations. That study used regression analysis to show that total population, average household size, population growth rate, domestic per capita income, number of firms and position of competitor banks are important factors affecting the performance of a bank branch. In Ref. [2], a decision support system for locating bank branches was developed with population, income level, cultural characteristics, number of firms, total deposits, growth potential and competitive situation as the main determinants. In Ref. [12], having previously identified five main criteria (demographic and socioeconomic factors, banking indicators, recruitment in accordance and trade potential) a decision support model for bank branch location selection was designed

[1] For instance, business areas (zones with retail establishments) will have greater cash needs than industrial zones.

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004

using the fuzzy Analytic Hierarchy Process (AHP). The Analytic Hierarchy Process is also used in Ref. [13] for suitable fire site selection. In Ref. [18], mathematical programming was used to present a method for reorganizing the bank service network by combining geographical information systems (GIS) representing geographical/social attributes- with demand-covering models. More recently, in Ref. [28], the hybrid method of AHP and Monte Carlo simulation was used in order to prioritize locations and select the best. Also, the authors compared the results statistically, using both descriptive and inferential statistics. In Ref. [3], a more sophisticated model for selecting optimal site location was proposed that integrate available data sources and decision models such as AHP, Geographic Information System (GIS) and the Maximal Covering Location Problem (MCLP).

These approaches were developed under the scope of solving related problems: firstly, how to identify the most commonly used criteria for deciding on branch location, by weighting possible criteria and sub-criteria; secondly, how to determine the best potential sites using GIS-based software (often, the first and second points are jointly analyzed as “to prioritize and select the appropriate location”); and thirdly, the ex-post application of methods to ensure that optimal locations are found in relation to the previously fixed criteria (such as MCLP, in order to maximize demand coverage, e.g., when there is a limited budget for establishing new branches).

However, the approach proposed in this paper employs a different philosophy: each banking entity is an expert on its own situation and has its own notion of *optimal* location depending on its particular premises and current circumstances. Hence, in order to identify the most appropriate locations for a particular bank, primarily the notion of its “branch success” must be defined. Once this has been specified (i.e., its most successful branches have been identified), the next step is to minimize the distance from the candidate-site’ features to that of the successful branches in an attempt to imitate the existing locations that work very well.

The remainder of the paper is organized as follows. While section 2 sets out the problem of identifying and selecting criteria, section 3 addresses criteria categorization, where the factors are divided into external and internal groups. Such a broad division of factors is necessary for operational purposes when developing the decision support model. Section 4 provides an overview of the quantification of special data (qualitative banking data and multi-factors, i.e., criteria with sub-criteria) as an interim step towards the branch site selection model. Section 5 involves the model design. Section 6 develops a minimization structure for branch opening costs and, finally, section 7 concludes the paper.

2. Identification of the factors

Regardless of research perspective, any attempt to address the branch site selection problem involves identifying the key factors governing that choice. The next step towards the selection of the best branch site is to decide upon which criteria are to be used.

As explained in the literature review above, there is a wide range of criteria used to optimally situate a bank branch. Following [19], the major ingredients for deciding where to locate branch-banks are: growth rates of deposits and loans, degree of competition, easy accessibility, and operating costs of potential sites. Other determinants are based on socio-economic attributes: demographics and behavioural factors that are ill-defined and *fuzzy in nature*. We will cover the issue of fuzziness in the following section.

The multi-criteria nature of the problem implies considering both criteria and sub-criteria. For instance, if the first criterion is the position, various sub-criteria may be utilized: the effect of proximity to wealthy residential areas and the distances between branches, as in Ref. [19], while [17] and [10], consider commercial areas and huge economic organizations instead. When all costs are independent of location, the choice will then be guided by proximity to potential customers, competing organizations and centers of economic activity in general, [16]. More detailed information on this may be found in Ref. [6]. Despite it not being the principal aim of this work to list all branch factors that may affect a location choice, the main ones identified from a detailed review of the available literature are presented in Table 1.

3. Factor categorization

In addition to the wide range of existing criteria for site selection, several categorizations can be made. We have chosen to split branch features into external and internal groups. External determinants may include population data (population size/density) and availability of certain support services such as secondary schools and hospitals, while internal characteristics include “a banking institution’ own’ features” such as its own’ arrangements or accounting data.

This categorization is merely operational: while internal features will allow us to incorporate the specific characteristics and arrangements of banking institutions into the model, external ones will point out the most appropriate location for the new branch. In fact, since our model is based on imitating the best existing choices' features, the part of the model outputs based on external factors will provide suitable potential areas which should be considered as the most desirable locations. This will be explained in detail in the decision model in section 5. The remainder of this section is devoted to showing some special features of both external and internal determinants.

3.1. External factors: local demographics

As acknowledged earlier, external factors have a great specific weight in the decision model since they indicate the most desirable (best) areas in which to locate a new branch. Although there are many other forms, external factors can be identified with local demographics, as described above. Some reflections on these are therefore necessary since local demographics exhibit special features that may distort a unified forecasting procedure with regard to signalling geographic areas.

Demographic parameters have to be carefully managed due to their *fuzzy nature*: take as an example the fact that branch managers usually categorize branches as being city centre’, rural’ or a business centre’, depending not (only based) on the geographical location of the branch but also on the number and amount of transactions. Without a clearly defining these characteristics, although a branch is geographically located in a rural area, it could be considered by practitioners as city centre’ if its number and amount of transactions exceeds the internal benchmarks for rural branches. Actually, this categorization of branches is quite unclear because the distinction between urban and rural areas is growing fuzzy, see Ref. [4]: while the main criteria for defining this commonly include population parameters, the combination of criteria/thresholds applied may vary greatly across countries. These major variations in demographics specified using “local” -as opposed to “internationally-accepted”- parameters make it very difficult to design a unified procedure for the optimal placement of a bank branch that fits all contexts. The fuzziness of these parameters is bypassed by the model developed in the following section (paragraph 4.2).

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004

Table 1
Site selection main factors.

Factors	Sub-factors
Number of potential customers	Daytime population
	Education level
Socioeconomic situation	Number of houses
	Summer houses
	Education places, universities, colleges
Social potential	Entertainment places, parks
	Hospitals
	Financial institutions
	Number of works places
Commercial potential	Shopping centers
	Parking facilities, car services
	Restaurants
	Cooperatives, gas stations
Competition	Number of competitors' bank branches
	Type of bank services provided by competitors
Financial situation	Average household income
	Total family income, bank-robbery rate
	Ease of travel
Ease of access	Proximity to public transport
	Traffic crossings in the area
	Major transportation arteries including highways
	Population growth
	Population size/density
Growth potential	Percentage of married couples
	Percentage of senior citizens
	Rate of returns, capital cost
Investment data	Property taxes, depreciation
	Insurances, and investment budgets.
	Strategic bank business policies
Policy data	Local and federal government laws and regulation

Table 2
Quantifying local demographics.

z_1	z_2	z_3	d_{min}	d_{max}
0	0	0	1.0	1.0
0	0	1	1.0	1.1
0	1	0	1.0	1.1
0	1	1	0.9	1.1
1	0	0	1.0	1.1
1	0	1	0.9	1.1
1	1	0	0.9	1.1
1	1	1	0.8	1.2

z_1 = unemployment.
z_2 = density of population.
z_3 = percentage of foreign population.

3.2. Internal factors

Internal factors are characteristic features of each banking entity. Unfortunately, branch level information is usually confidential and not publicly available, a fact that greatly complicates the information gathering process. A good source for finding the main internal branch factors is the research literature related to branching efficiency.[2] Therefore, while reviewing notion(s) and methods for evaluating branching efficiency, internal branch determinants are brought to light.

Let us start with banking efficiency. The most commonly used definition of banking efficiency is based on the tools employed to measure operating banking efficiency. These techniques (classical accounting ratios such as returns on assets and returns on investment, linear programming -DEA- or stochastic methods -SFA, DFA- and their variants, [5]), [24], assign a *numerical score* to financial institutions allowing for comparison amongst them as well as identifying those which are not efficient enough if their benchmarks do not reach certain confidence levels. This underlies the definition of banking efficiency: the greater the bank benchmark, the more efficient the banking institution. Some authors justify the fact that the analysis of efficiency unit has typically been a bank rather than an individual branch of the bank due to the lack of easy access to branch-level data. In reality, efficiency studies at the branch level are relatively few when compared to those pertaining to banks as a whole.

Importantly, in the same way that the analysis of the financial institutions' performance allows a ranking of the firms, branching efficiency could be used to rank the branches: positioning the branches with respect to each other in terms of their efficiencies in a competitive environment, [22]. Actually, ranking the branches would allow identification of the best: this fact is of capital importance for our decision model since it is based on imitating the best existing choices.

In the existing literature, there are various underlying insights into branching efficiency: Paradi, Yang and Zhu [23], distinguish between three approaches for assessing efficiency: production, profitability and intermediation approaches. The production approach evaluates the branch using inputs (labour, capital and space) to generate outputs (loans, deposits and insurances). The profitability models study how efficiently a branch uses its inputs cost factors to create revenue from outputs. Finally, the intermediation approach considers the branches to be intermediaries collecting funds for loans and other profitable activities. This is closely linked to the technical efficiency notion (the maximum output produced from the minimum quantity of inputs). Both ideas suggest minimizing all related costs: as we shall in section 6, the banks' main goal when opening a new branch is to make costs as low as

[2] This notion was firstly suggested in Ref. [8], where the authors pointed out that branch efficiency literature was much less complete than banking efficiency literature.

possible (see Ref. [20]). All in all, the information collected through these surveys (inputs and outputs) may be used as internal branch determinants.

4. Quantifying the factors

Let us now look at branch site selection under the location-allocation perspective.[3] In these surveys (see Ref. [10] or [27]) two factors are highlighted: the costs of providing services and the *quality* of the services provided. Both can serve as examples of quantitative versus qualitative factors whose scoring might be addressed differently: actually, while quantitative factors (like branch costs) are easily and internationally accepted, qualitative ones (including quality of the service provided) are not. For that reason, this section is aimed at briefly examining the way in which special types of branch determinants may be quantified. This information could be used when, at some stage of the future decision making process, scoring of branch feature vectors is required.

4.1. Quantifying qualitative factors

Some considerations on the way in which qualitative banking data can be measured are presented here. The following procedures apply to interviews, surveys and focus group data.[4] Basic methods for converting qualitative individual' perceptions or assessments into quantitative data include tables, scales or illustrative analysis of preference evaluations:

- One-Way Tables are the most straightforward form of analysis as they allow tabulation of results, question by question.
- Cross-Tabulation (Two-Way and Higher-Way Tables) are used when each question has multiple possible answers as the table breaks the total sample down.

Other different measurement methods for quantifying qualitative banking data, (see Ref. [21]), are:

- quantification methods based on common subjective probability distributions. The first was suggested by Theil [32] in order to provide an alternative to the use of balance statistics in the quantification.
- The probability method, by Carlson and Parkin [29]. The method was independently discovered by Knobl [30] and Carlson and Parkin [29] and it assumes that agents report expected changes only if this changes are above or below an indifference threshold.
- The regression approach, suggested, as an alternative, by Pesaran [31], in which quantitative expectations are function of a specific regression model rather than a specific probability distribution.

Here, we focus on methods which supply aggregate expectation measures. From these, a range of procedures for quantifying qualitative data has been developed. Many others are available for dealing with qualitative information that can be coded either as binary variables (Yes/No, presence/absence type data) or as categorical variables (high, medium or low levels of access to regional facilities, for instance). If factors affecting qualitative features of the binary sort are to be explored, logistic regression modeling can be also used.

It should be noted that the final objective of the brief overview of scoring/ranking methods in this paragraph is to provide tools that may be applied when the need to rank the bank branches arises at some stage of the forthcoming decision model. In any case, each banking entity undoubtedly has its own scoring system to evaluate its branches.

4.2. Quantifying multi-factors and fuzzy factors: local demographics

Some branch determinants may in turn be affected by several sub- determinants. This paragraph is aimed at describing a robust method of quantifying factors which depends on several parameters. This method also bypasses the fuzziness of (sub-)parameters by allowing them to be processed only when applicable.

Local demographics (hereinafter referred to as d) are key factor for site selection models that depend on many variables (multi-factor), measured differently in each country (fuzzy factor). In order to overcome the wide range of demographic parameters, d must depend on binary variables that make it equal to 1 if it applies and 0 if not. This allows the widest range of cases to be covered since these sub-parameters can be processed only when applicable. Moreover, a range of values $d \in [d_{min}, d_{max}]$ may be considered instead of a single one.

As an illustrative example ([14]) we consider the following three geographical variables as determinants of branch location with regard to demographic factors: $z_1 =$ unemployment, $z_2 =$ density of population and $z_3 =$ percentage of foreign population. Thus, the values of local demographics are determined by the values of the chosen geographic variables z_i, according to a table as follows (see Table 2):

This argument can be easily extended when either more variables are needed or a wider range of variable' values is considered: both the variables and the number of these can be freely selected.

5. The decision support model for bank branch site selection

As mentioned before, the literature shows that, while there are a wide range of approaches that may be used for handling the bank branch location problem, there is no single procedure that fits all needs. We shall take advantage of each bank branch success' notion in order to establish a general procedure that may should help decide the best branch location in all cases. Thus, in this paragraph, we start from the assumption that the best location for a new branch needs to be determined.

5.1. Define bank branch success

This paragraph is aimed at developing a setting of bank branch success that is as general as possible in order to cover the majority of scenarios. Our final goal is to comprehend the full range of internal bank regulations as well as bypassing the fuzziness on some measurement parameters.

Branch managers define bank branch success according to several factors: but they undoubtedly do according to their banking institution' own internal arrangements. That is, they completely know what branch success means for their banking institution. On the one hand, since inside the same bank branch network there are differentiating branch features, the notion of branch success would be specifically defined for a category of branches.[5] On the other hand, once the category of branches has been defined, a criterion

[3] Within the literature, this is commonly known as facility location problems with immobile servers, stochastic demand and congestion (see Ref. [9]).

[4] The example considered is the bank branch service quality.

[5] Practitioners usually group the branches into city centre', rural' or business centre'.

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004

has to be selected according to a priority objective for the considered entity in the current socioeconomic circumstances: with regard to this criterion, branch managers may indicate which branch (or which group of branches) is the most successful. In consequence, we may assume that the concept of branch success is set by each banking institution. Thus, in order to identify the best site for a new branch, two previous steps (pre-processing steps) are necessary:

Step 1 A category of branches should have been specifically defined. This limits the problem since the new branch (for which the best location is being decided) belongs to this category.

Step 2 A criterion has to be selected according to a *priority objective* for the considered entity in the current socioeconomic climate. This selection may be made through ad-hoc methodologies, where priorities are identified from a list of possible criteria by expert judgments made on pairwise comparisons.[6] Thus, the best site will be sought in relation to this criterion.

In order to achieve our goal, let us recall the notion of *feature vector*. In pattern recognition and machine learning, a feature vector is an n-dimensional vector of numerical features (or qualitative features which may be quantified somehow) representing an object. For operational purposes, we consider that the features are categorized into two main groups, where $b = (ex_b, in_b)$ is a feature vector representing a branch b, in which ex_b denotes a sub-vector formed by branch external features and in_b denotes a sub-vector formed by branch internal features (see section 3 for further details).

This process mainly consists of the following (processing) steps:

Step 3 Branch-specific main features[7] have to be chosen according to the criterion (selected according to a priority objective). Note that the different entities would probably choose different features or the even same entity may select different features depending on different socioeconomic scenarios.

Step 4 A feature vector is attached to each branch. This feature vector should contain "the most significant branch features" from step 3. Hence, we shall consider that a branch b is equal to a feature vector subdivided into external (ex_b) and internal factors (in_b):

$$b = \begin{pmatrix} ex_b \\ in_b \end{pmatrix}.$$

Step 5 Numerical values are taken for each factor as scores. Some of the factors may be easily quantified (quantitative determinants like branch costs) while others (qualitative determinants) may be quantified using other tools (see section 4).

Once a numerical vector formed by the scores for the main features is attached to any branch, the highest scores indicate the most significant branches, i.e., the successful ones. The notion of branch success may be extended in a fuzzy way: i.e., a range of values can be considered instead of a single one for all determinants:

Definition 1. A branch b^* is considered to be successful if its numerical-valued feature vector, in all vector entries, moves in a closed interval[8] $[\underline{\quad}^{*}_{b}, \text{—}^{*}_{b}]$ fixed by bank experts for each entity.

5.2. Do not deviate from branch success

Once the successful branches have been highlighted, the key decision to be made with regard to the branch site selection problem is to choose the site closest to the successful branches, as defined above (Definition 1).

When are two branches close to one another? This does not mean that they are in physically proximity. If geographical distance is not necessarily required, some notion of distance might be thus specified. Then, the distance between two branches is defined through their corresponding feature vectors as follows:

Definition 2. **(Distance between branches).** The distance between two branches $b_i = (ex_{b_i}, in_{b_i}), b_j = (ex_{b_j}, in_{b_j}),\ i \neq j$, is the Euclidean distance between their corresponding feature vectors:

$$d(b_i, b_j) = +\sqrt{\left(ex_{b_i} - ex_{b_j}\right)^2 + \left(in_{b_i} - in_{b_j}\right)^2}. \qquad (1)$$

Once the distance between branches has been stated, the branch site selection' model will be developed based on *imitating branch success*. In other words, our model seeks to minimize the distance between the candidate-branch and the successful one, according to the following result:

Theorem 3. *The problem of finding a branch with minimum distance to a successful one has at least one solution.*

Proof. According to Weiertrass's Extreme Value Theorem, for a real-valued continuous function ($d(b_i, b_j)$) on a non-empty compact domain, there exists global minimum. The extremum occurs either at critical points within (in the interior) or at the end points of the interval.

In regard to the aforementioned non-empty compact domain, it should be noted that this optimization programme is a multivariate minimization problem where each variable belongs to a closed interval, the corresponding one assigned by Definition 1. Hence, since the cartesian product of compact sets is compact, the result follows.

It should be noticed that any other definition of distance may be considered if more appropriate to the context, provided that it is a continuous function (the non-empty compact domain is provided by the cartesian product of closed intervals such as $[\underline{\quad}^{*}_{b}, \text{—}^{*}_{b}]$). However, regardless of the definition adopted, our model will still function on the basis of *imitation of branch success by minimizing the distance to the successful branches*.

This principle further extends the decision model' steps:

Step 6 Minimize the distance amongst the branch-candidate and the most successful branches. For this, the input is the feature vector of the branch-candidate, which has as many variables (non numerical-valued) as there are external and internal features, leading to a constrained multivariate minimization problem that has at least one solution (Theorem 3).

The outputs are vectors with minimum distance to successful branches, which comprise external and internal features. The first part of these vectors contains all external features which have to be

[6] See Ref. [3] or [6] for instance.

[7] Those factors which are particularly relevant for the current case must be selected amongst all factors/determinants which influence branch size. When these factors become coordinates of the feature vector, they are called features.

[8] A different closed interval is considered for each vector entry, i.e., there are as many intervals as there are vector entries. Hence, the feature vector belongs to the cartesian product of the closed intervals.

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004

imitated. This would offer an appropriate area for locating the new branch.

Note that, whereas the first features allow the identification of the best site(s) for the new branch, the second ones guarantee the preservation of all the entity' own characteristics throughout the process.

As mentioned before, it is not necessary to consider only a single successful branch as a group may be used. That is, the minimization of distance between the candidate and the most successful branch one may apply simultaneously to a group of branches within the same category. Thus, the process would run in parallel thereby producing more than one output.

The fact that more than one output may be expected enhances the range of possible choices. This leads to the final step in the decision model:

Step 7 From all outputs, select the most convenient according to pre-fixed criteria. Such criteria may take many forms including minimizing costs (total setup cost, fixed cost, total annual operating cost etc.), minimizing the longest distance from the existing facilities (average time/distance traveled, maximum time/distance traveled, etc.) and maximizing service… Whether or not new locations are *physically close* to existing branches is left to the bank manager' judgement since this contingency depends on each bank' requirements, which in turn depend on current socio-economic circumstances and priorities. Hence, while it is unusual to open new offices in the proximities of existing ones, in specific areas, this greater capacity (more branches near each other) could meet an increase in demand.

Finally, in our decision model, the last choice to be made in step 7 relates to minimizing branch opening costs. This is discussed in next paragraph.

In summary, the decision model is as follows:

6. Minimizing the cost of branch opening

Opening a branch has a related price. This cost, which should always be minimized, consists of two components: branch opening costs and service provision costs. This first is related to immediate expenses such as refurbishment, security, and equipment costs. The second ones, to operating costs, including employee-related costs. For ease, here we simply refer to "opening costs" as the all costs involved when opening a branch.

The banks' main goal when opening a new branch is to reduce costs as much as possible (see Ref. [20], where the authors present a non-linear re-structuring model, aimed at redesigning the bank network at a minimal cost). The intention of our decision model is also to maintain this premise:

$$\begin{aligned} &\textit{Minimize}: \textit{branch opening costs}\ (b) + \textit{service provision costs}(b) \\ &s.a \quad \left\{ \begin{array}{c} \textit{each numerical} - \textit{valued feature vector entry of } b \\ \textit{belongs to closed intervals such as} \left[\underset{b}{\overset{*}{-}}, \overset{*}{\underset{b}{-}}\right] \end{array} \right. \end{aligned}$$

The minimization of branch opening costs specifies the criterion followed in previous sept 7: i.e., the site that is finally selected is that which minimizes an appropriate branch opening cost function. Hence, the final step is the following:

Step 7' From all minimization programme' outputs, select the one which minimizes the branch opening costs.

7. An illustrative example

Implementing the proposed method implies a huge quantity of branch data. It should also be added that this information is not publicly available. While this does not represent a problem for banks themselves, this limitation prevents any type of proper[9] model validation. This section is therefore devoted to showing the functioning of the proposed methodology using a didactic example intended for illustrative purposes.

For this, let us suppose that a banking entity is facing the following scenario: an existing branch is overburdened due to prolonged excess demand. This branch is located in a rural area whose potential is expected to increase in the coming years as a result of territorial re-distribution and expansive rezoning. In consequence, the entity must assess the possibility of opening a new additional branch in the area to either absorb the excess demand or confront the entry of competitors into the area (or both).

Thus, according to the proposed methodology, the following steps should be taken:

Step 1 A category of branches should have been specifically defined. According to the categorization of branches as city centre', rural' or business centre', here the selection should be **rural**.

Step 2 A criterion has to be selected according to a priority objective for the entity in the current socioeconomic climate.

The priority objective is either to absorb the excess demand or face the entry of competitors (or both contingencies). Since the banking entity already has a branch in the zone, a reasonable criterion could be **size** in order to select **small**, provided that branches may be categorized as large, medium and small. The specific size of the branch (small or medium?) would depend on the size of that demand.

Step 3 Branch-specific main features have to be chosen according to size, as the selected criterion. This means that those factors particularly relevant to the present case have to be selected amongst all factors/determinants which influence branch size. When these factors become coordinates of the feature vector, they become called features.

There are many factors that influence branch size. In addition, branch managers use several ways to quantify the size of a branch: the volume of credits, the number of business/private clients, the number of staff, the volume of deposits, or the allowed cash threshold for large deposits[10], amongst other criteria. Branch size is not a closed concept: on the contrary, it may be measured through several parameters. In general terms, the most accepted is to consider the size of a branch as an increasing function of the total branch cash needs: bigger branches correspond to bigger movements -entries and exits- of liquid resources (see Ref. [14]). For all these reasons, a very high number of possible factors may be

[9] Here "proper" means "not intended for illustrative purposes". In fact, there are severe difficulties when accessing sufficiently detailed real banking data at the branch level. As a consequence, only a few studies are supported by real banking records, as mentioned in Ref. [15]. This author argues that branch literature is much less complete than banking literature due to the lack of easy access to branch-level data.

[10] The allowed cash threshold for large deposits is considered a branch size benchmark, i.e., a key sign of a branch' ability to manage their liquid resources: a low threshold for deposits is seen in those branches that are unable to handle big deposits (small branches) while larger branches, able to handle high volumes of cash, have high deposits thresholds.

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004

Fig. 2. Option selector.

expected (see Fig. 2).

In such cases (when a huge quantity of factors is managed), tables like the one shown in Fig. 3 (which is a simplification) are useful for conducting the factor selection procedure. Importantly, implementing these procedures into algorithms should provide an easy-to-handle system (see the Conclusions section for further details).

Once the factors have been selected, a feature vector may be attached to each branch (**Step 4** of the model). In the next step (**Step 5**), numerical values can be assigned to each factor in accordance with the entity's own internal branch scores. Indeed, it is assumed that long-established banking entities would have up-to-date information available on their efficient and under-performing branches as this is periodically assessed,[11] either for internal control purposes or to comply with legislation.

Finally, the remaining steps must be carried out to complete the site selection procedure:

Step 6 Minimize the distance amongst the branch-candidate and the most successful branches.
Step 7 From all outputs, select the most convenient according to pre-fixed criteria, which is "size" in our case.
Step 7' From all minimization programme' outputs, select the one which minimizes the branch opening costs.

8. Conclusions

This paper deals with the single branch site selection' problem in the banking context under the assumption that it is one of the most important decision making processes for banks. However, the high level of complexity (several factors have to be taken into consideration in the decision making process as well as a wide range of internal requirements for the various entities) has meant that, to date, here is no one-size-fits-all procedure. This paper attempts to provide a unified approach based on each banking institution' notion of branch success, that would work well for all kind of branches. On the one hand, it can be adjusted as required and tailored to suit the specific requirements of each banking institution (or each kind of candidate-branch). Moreover, this can be achieved at the least possible cost since all necessary fine-tunings can be carried out throughout the banking institutions' own computer services. On the other hand, the generality of the proposed method would also allow it to be applied -with minor changes- to supermarkets, petrol stations, or other businesses with branches. Such a global approach is beneficial in several ways: e. g, decreasing costs by replacing several local approaches with a universal one.

It should be noted that, under the proposed methodology, an existing set of successful bank branches should be provided as reference points as the search for new (optimal) locations consists of imitating the features of these reference points as closely[12] as possible. A similar data set of reference points would be required for non-banking entities, which may or may not exist, although large banking institutions undoubtedly have up-to-date information available on successful and under-performing branches, as this is periodically assessed,[13] either for internal control purposes or to comply with current legislation (for instance, regulatory reforms that set the safety liquidity levels that banks must attain -Basel III rules).

In the minimization programme proposed, several changes can be made according to different scenarios. These include: firstly, that the classical notion of Euclidean distance may be replaced by other definitions which would be more suitable. For this, normalized correlation, pattern intensity squared and many others methods (from image similarity metrics for instance) may be useful depending on the specific situation. Specifically, while there are more distances which could be considered, two kinds of measures may be used to estimate the relationship between two objects: *distance measures* and *similarity measures* (giving rise to similarity functions like the well-known Pearson correlation measure). In the first group, the distance would vary depending on the *type of data attributes*: *numeric attributes* (the similarity between two data instances may be calculated using the Minkowski metric, with the well-known Euclidean distance as a particular case), *binary*

[11] In relation to banks, the usual techniques for evaluating the efficiency are classical accounting ratios such as returns on assets and returns on investment, linear programming -DEA- or stochastic methods -SFA, DFA- and their variants, which assign a numerical score to financial institutions allowing them to be compared (as solid blocks) as well as identifying those which are not efficient enough if their benchmarks do not reach certain confidence levels. As far as branches are concerned, Berger, Hanweck and Humphrey [7], and Paradi, Yang and Zhu [23], distinguish between three approaches to assessing efficiency: production, profitability and intermediation approaches. The production approach evaluates the branch using inputs (labor, capital and space) to generate outputs (loans, deposits and insurances). The profitability models study how efficiently a branch uses its input cost factors to generate revenues from outputs. Finally, the intermediation approach considers the branches to be intermediaries collecting funds for loans and other profitable activities, see Ref. [1], and [26].

[12] The term "close" means the minimum distance between the successful location(s) and the candidates.

[13] Related to banks, usual techniques to evaluate the efficiency are classical accounting ratios such as returns on assets and returns on investment, linear programming -DEA- or stochastic methods -SFA, DFA- and their variants, which assign a numerical score to financial institutions allowing for comparison amongst them (as solid blocks) as well as identifying those which are not efficient enough if their benchmarks are not into some levels of confidence. As far as branches are concerned, Berger, Hanweck and Humphrey [7], and Paradi, Yang and Zhu [23], distinguish between three approaches to assess efficiency: production, profitability and intermediation approaches. The production approach evaluates the branch using inputs (labor, capital and space) to generate outputs (loans, deposits and insurances). The profitability models study how efficiently a branch uses its cost factors of inputs to create revenues from outputs. Finally, the intermediation approach considers the branches as intermediaries collecting funds for loans and other profitable activities, see Ref. [1], and [26].

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004

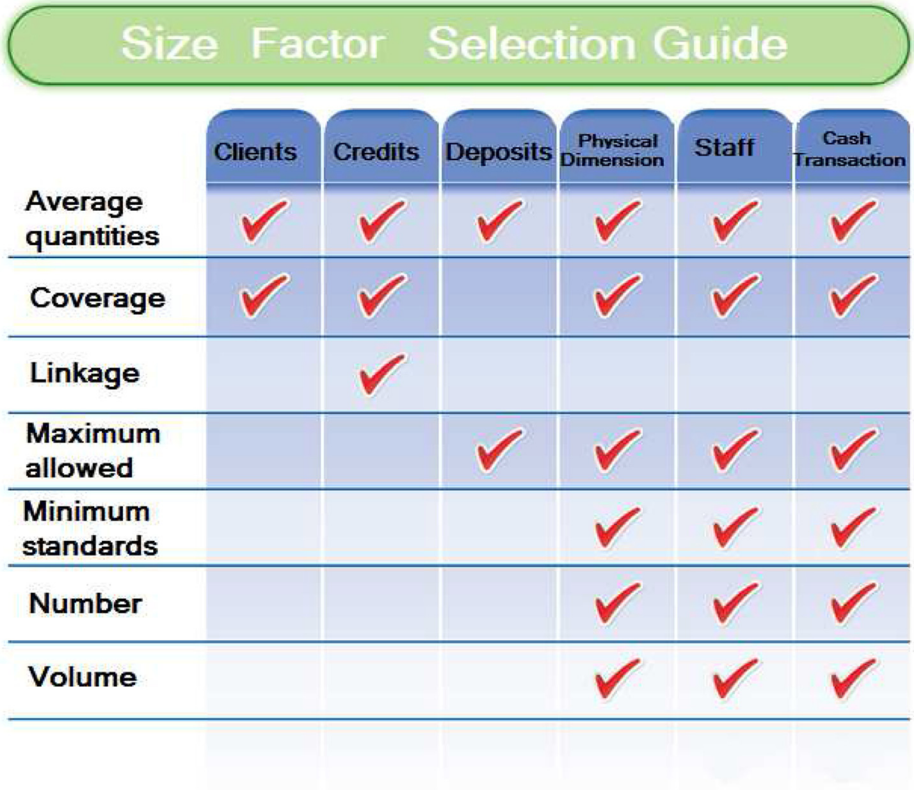

Fig. 3. Size options selection guide.

attributes (the distance between objects may be calculated through contingency tables), and other types such as *nominal, ordinal or mixed-type attributes* for which specific definitions of distance are required. The choice of Euclidean distance for the proposed methodology is based on two points: firstly, branch features are usually *numerical attributes*, that can be quantified by using the corresponding techniques (discussed in section 4 “Quantifying the factors”). Secondly, Euclidean distance is the most common measure for *geographical* distance, which may be taken into account as an additional branch feature when constructing the feature vector. Moreover, Euclidean distance is the most widely known.

A second variation could be to fix some of the variables that comprise the corresponding feature vector, which would be the case of pretending a higher level of similarity between the candidate-branch and the successful ones. In any case, changes may be implemented as needed.

It should be noticed that, when numerically-valued examples are attempted, a huge quantity of output data has to be managed. However, this theoretical setting may be easily converted into an algorithm (or into an expert system): this is a future research project within a foreseeable period of time.

Acknowledgements

Financial support from the excellence project of the Spanish Ministry of Science and Innovation “Mecanismos de resolución de crisis: cambios en el sistema financiero y efectos en la Economía real” (P12-SEJ-2463). The author also thanks the financial support for the project received from by of the Regional Government of Andalusia “GAMMA (Grupo de Análisis Microeconómico y Macroeconómico Aplicado)” (SEJ340).

References

[1] Athanassopoulos AD. Nonparametric frontier models for assessing the marketand cost efficiency of large-scale bank branch networks. J Money Credit Bank 1998;30(2):172–92.
[2] Abbasi GY. A decision support system for bank location selection. Int J Comput Appl Technol 2003;16:202–10.
[3] Allahi S, Mobin M, Vafadarnikjoo A, Salmon C. An Integrated AHP-GIS-MCLP Method to Locate Bank Branches. Industrial and Systems Engineering Research Conference. 2015.
[4] André M, Mahy G, Lejeune P, Bogaert J. Toward a synthesis of the concept and a definition of the zones in the urban-rural gradient. Biotechnol Agron Soc Environ 2014;18(1):61–74.
[5] Avkiran NK. Developing foreign bank efficiency models for DEA grounded in finance theory. Soc Econ Plan Sci 2006;40:275–96.
[6] Basar A, Kabak O. Identifying the criteria and their priorities for locating bank branches in Turkey. Int J Anal Hierarchy Process 2014. Conference paper.
[7] Berger AN, Hanweck GA, Humphrey DB. Competitive viability in banking: scale, scope and product mix economies. J Monet Econ 1987;20:501–20.
[8] Berger AN, Leusner JH, Mingo JJ. The efficiency of bank branches. J Monet Econ 1997;40:141–62.
[9] Boffey B, Galvao R, Espejo L. A review of congestion models in the location of facilities with immobile servers. Eur J Oper Res 2007;178:643–62.
[10] Boufounou PV. Theory and methodology, evaluating bank branch location and performance: a case study. Eur J Oper Res 1995;87:389–402.
[11] Cerutti E, Dell' Ariccia G, Martínez Pería MS. How banks go abroad: branches or subsidiaries? J Bank Finance 2007;31:1669–92.
[12] Cinar N. A decision support model for bank branch location selection. World Acad Sci Eng Technol 2009;60:126–31.
[13] Chaudhary NP, Chhetri SK, Joshi KM, Shrestha BM, Kayastha P. Application of an Analytic Hierarchy Process (AHP) in the GIS interface for suitable fire site selection: a case study from Kathmandu Metropolitan City. Soc Econ Plan Sci 2016;53:60–71.
[14] García Cabello J, Lobillo FJ. Sound branch cash management for less: a low-cost forecasting algorithm under uncertain demand. Omega 2017;70C:118–34. http://dx.doi.org/10.1016/j.omega.2016.09.005i.
[15] Das A, Ray S, Nag A. Labor-use efficiency in Indian banking: a branch-level analysis. Omega 2009;37:411–25. http://dx.doi.org/10.1016/j.omega.2007.05.002.
[16] Korkel M. On the exact solution of large-scale simple plant location problems. Eur J Oper Res 1989;39:157–73.

[17] Meidan A. Distribution of bank services and branch location. Int J Bank Mark 1993;2:60–72.
[18] Miliotis P, Dimopoulou M, Giannikos I. A hierarchical location model for locating bank branches in a competitive environment. Int Trans Oper Res 2002;9(5):549–65.
[19] Min H. A model-based decision support system for location banks. Inf Manag 1989;17(4):207–15.
[20] Monteiro M, Fontes D. Locating and sizing bank-branches by opening, closing or maintaining facilities. Oper Res Proc VIII 2006:303–8.
[21] Nardo M. The quantification of qualitative survey data: a critical assessment. J Econ Surv 2003;17:645–68.
[22] Oral M, Yolalan R. An empirical study on measuring operating efficiency and profitability of bank branches. Eur J Oper Res 1990;46:282–94.
[23] Paradi JC, Zhu H. A survey on bank branch efficiency and performance research with data envelopment analysis. Omega 2013;41:61–79.
[24] Portela MCAS, Thanassoulis M. Malmquist-type indices in the presence of negative data: an application to bank branches. J Bank Finance 2010;34: 1472–83.
[26] Thanassoulis E. Data envelopment analysis and its use in banking. Interfaces 1999;3:1–13.
[27] Vidyarthi N, Jayaswal S. Efficient solution of a class of location-allocation problems with stochastic demand and congestion. Comput Oper Res 2014;48:20–30.
[28] Zainab L, Zahra NA, Mostafa K. Locating the bank branches using a hybrid method. Tech J Eng Appl Sci 2014;4(3):124–34.
[29] Carlson J, Parkin M. Inflation expectations. Economica 1975;42(166):123–38.
[30] Knobl A. Price expectations and actual price behaviour in Germany. Int Monetary Fund Staff Papers 1974;21:83–100.
[31] Pesaran MH. Expectations formations and macro-econometric modelling. In: Malgrange P, Muet PA, editors. Contemporary macroeconomic modelling. Oxford: Basil Blackwell; 1984.
[32] Theil H. On the time shape of economic microvariables and the Munich business test. Revue Inst Int Stat 1952;20:105–20.

Julia García Cabello held a PhD in Pure and Applied Mathematics from the University of Granada where she has been teaching since 1990. Prior to arriving to the mathematical/economical world, she developed a successful career in Algebra (known as JG Cabello), publishing in flagship journals on Algebraic Homotopy Theory. Today, she is fully tenured professor and full researcher at the *Applied Mathematics Department, Faculty of Bussiness and Economics of the University of Granada (Spain)*, where she teaches undergraduate, MBA and Executive MBA courses and conducts seminars on a wide range of business-related topics. Her current research interests include Financial Mathematics and Mathematical Modeling in Banking. To this regard, she is currently involved in several national and international research projects. Her recent works include articles in optimizing liquidity resources for bank branches and ATMs, published in journals such as OMEGA (The international Journal of Management Science) or EJOR (European Journal of Operational Research). Julia García Cabello is also reviewer at related journals.

Please cite this article in press as: Cabello JG, A decision model for bank branch site selection: Define branch success and do not deviate, Socio-Economic Planning Sciences (2017), http://dx.doi.org/10.1016/j.seps.2017.09.004