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A support system that delineates location-choice sets for firms seeking office space

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Abstract: Factors influencing the location decisions of offices include traffic, accessibility, employment conditions, economic prospects and land-use policies. Hence tools for supporting real-estate managers and urban planners in such multidimensional decisions may be useful. Accordingly, the objective of this study is to develop a GIS-based tool to support firms who seek office accommodation within a given regional or national study area. The tool relies on a matching approach, in which a firm's characteristics (demand) on the one hand, and environmental conditions and available office spaces (supply) on the other, are analyzed separately in a first step, after which a match is sought. That is, a suitability score is obtained for every firm and for every available office space by applying some value judgments (satisfaction, utility etc.). The latter are powered by a focus on location aspects and expert knowledge about the location decisions of firms/organizations with respect to office accommodation as acquired from a group of real-estate advisers; it is stored in decision tables, and they constitute the core of the model. Apart from the delineation of choice sets for any firm seeking a location, the tool supports two additional types of queries. Firstly, it supports the more generic problem of optimally allocating firms to a set of vacant locations. Secondly, the tool allows users to find firms which meet the characteristics of any given location. Moreover, as a GIS-based tool, its results can be visualized using GIS features which, in turn, facilitate several types of analyses.

Keywords: Office site selection, decision support system, geographic information systems

1 Introduction

The location of offices is strongly determined by urban environmental features such as traffic and accessibility, land-use policies, infrastructure conditions, availability of buildings, economic and market prospects, employment locations and others, all acting together (e.g., Elgar et al., 2009; Louw, 1998; Bell, 1991). So, given the significant role that offices play in society, the proper assessment of this interaction is very important to governments and developers alike.

Offices are necessary for the service sector, providing facilities for the population and offering employment opportunities. In that context, any low performance in one of the factors involving office firms and the urban environment would negatively affect the performance of firms - with clear economic and social implications. Some examples are worsened accessibility of services for customers and, consequently, a decrease of competitiveness; higher costs for required business travel to make deals between companies and establishments; and reduced accessibility for employees, resulting in negative social benefits due to a long journey and a possible decline in productivity.

Hence policy makers, urban planners and real estate managers are interested in locating office firms at locations that are optimal in terms of the business model of the firm and which limit any negative effects on society. Although various principles to this effect have already been defined, such as a compact city, the new urbanism and smart growth, it still requires a more refined coordination between the needs of office firms and the social and environmental implications of the spatial distribution of offices for optimality.

Considering the above, the present study seeks to contribute to the existing literature on office site selection. Our approach is based on a process of finding a suitable location for a given organization, in which both location characteristics and firm's requirements are analyzed through a process that tries to match all related aspects within a site-selection assessment.

Although the concept has been discussed before (e.g., Reitsma, 1990; Fedra and Reitsma, 1990; Lucardie, 1994; Witlox, 1998), this approach is relatively scarce as operational versions have never been fully developed. Moreover, the current state-of-the-art in multi-agent modeling and firm demographics offer new opportunities to advance it. The approach can be best understood in the context of the evolution of theoretical approaches towards site selection. Hayter (1997), Witlox and Timmermans (2000), van Dijk and Pellenbarg (2000), Pellenbarg et al. (2002), Brouwer et al. (2004), among other authors, extensively discuss the main theories and point to the related references throughout site-selection history.

To summarize, traditionally, location theories were based on economic principles such as distance minimizing for consumers and profit maximizing for firms, the so-called classical approach. Although it increased our understanding of the organization of space, the assumptions underlying this theory were too restrictive to develop policies or predict location decisions of firms. This led to the introduction of behavioral concepts such as preferences, motives, attitudes, limited information, evaluations and cognitive maps, which replaced the purely economic principles.

Thus, location decisions relied on preferences of decision makers that possibly were based on limited and perhaps biased information that they had about the choice options and their characteristics whenever they looked at locations which were or could be satisfactory. Behavioral approaches, however, did not escape criticism either. In particular, it was argued that existing behavioral theories do not incorporate firm's characteristics, structure and lifecycle. It was also argued that location decisions cannot be viewed independently, but should be evaluated in the context of a more general business model. Location is important, but then again it is only one component of a business strategy.

In line with the above, a potential site can be considered a suitable location if the characteristics of that location match the organization's requirements at a specific stage of its lifecycle, considering its general business strategy. This is the fundamental idea of the functional approach. In particular, three components interact in the decision making process:

1. the organization, which has a set of requirements;

2. the potential location sites, which have inherent characteristics; and
3. the relational matching mechanism, which links both organization requirements and location characteristics.

The results of this interaction determine the degree of site suitability. Therefore, having pointed out the matching approach on which we base our study, its specific aim is to build a GIS-based support system for delineating location choice sets for a firm seeking office space. It examines the location preferences under several aspects which may influence the site selection of office firms.

This paper is structured accordingly. In Section 2, we present a discussion about the proposed model based on the matching approach. Section 3 then presents the principles of the decision tables and expert knowledge that was used in this work to define some functions of the model. The decision support tool and the main issues about the software implementation are presented in Section 4. In Section 5 we present some illustrations and a discussion of preliminary results obtained with the tool. Finally, we finish this paper with some conclusions concerning the model, the decision support system, and some possible developments for the future, as presented in Section 6.

2 Functional specification

The model that we propose in this section is based on the functionality of a computational entity, referred to as an agent, which can be incorporated in a planning/decision support system for performing various tasks, such as delineating location choice sets for a particular firm, selecting firms for a particular site or defining the optimal allocation of a set of firms to a set of locations. It is based on the idea of modeling office site-selection decisions as a function of, on the one hand, the characteristics of the firm searching for office accommodation and, on the other hand, the characteristics (including location attributes) of potential office sites.

Let i (i=1,…,I) be a subscript indicating the set of locations within a study area and j (j=1,…,J) be a subscript for the set of firms being investigated. Assume that each location i can be described in terms of N physical characteristics X_{in} and each firm j can be described in terms of M firm characteristics Y_{jm} (e.g., type of economic activity, size etc.). Further, assume that decision makers, who represent firms, have a set of minimum requirements and objectives formulated in terms of a set of K performance characteristics Z_{jk}^{D} (e.g., accessibility by car, availability of workers, visibility of the site, etc.). The demands are a function of the firm's characteristics as described by Equation 1, where $\mathbf{Y}_j$ is the set of Y_{jm} firm characteristics (m=1,…,M).

$$Z_{jk}^{\mathrm{D}} = f(\mathbf{Y}_j) \tag{1}$$

On the other hand, the performance provided by a location i on each criterion k is denoted by Z_{ik}^{S} and modeled as a function of the location's physical characteristics as described by Equation 2, where $\mathbf{X}_i$ is the set of X_{in} location characteristics (n=1,…,N).

$$Z_{ik}^{\mathrm{S}} = g(\mathbf{X}_i) \tag{2}$$

We assume that for each combination of location i and firm j the agent (or support tool) is able to evaluate the degree of match, represented by Equation 3, where Q_{ijk} represents a matching score between supplied and demanded performance on criterion k and $\mathbf{Z}_i^{\mathrm{S}}$ and $\mathbf{Z}_j^{\mathrm{D}}$ are K-vectors of offered and demanded performance scores.

$$Q_{ijk} = h(\mathbf{Z}_i^{S}, \mathbf{Z}_j^{\mathrm{D}}) \tag{3}$$

Finally, we assume that the agent maps the matching characteristics into an evaluation space and then applies some value judgment V (satisfaction, utility etc.) to the overall match of location and firm. This is represented by Equation 4, where V_{ij} is a suitability score for housing firm j at location i and $\mathbf{Q}_{ij}$ is a K-vector of match scores.

$$V_{ij} = r(\mathbf{Q}_{ij}) \tag{4}$$

Hence, the basic information can be stored in a set of basic matrices:

1. an I x N matrix **X** describes the characteristics of the various locations;
2. a J x M matrix **Y** describes the characteristics of the various firms in the study area;
3. an I x K performance matrix $\mathbf{Z}^S$ of locations;
4. a J x K requirement matrix $\mathbf{Z}^D$ of firms;
5. an I x J x K matching matrix **Q**;
6. an I x J suitability matrix **V**.

In summary, using this set of functions the agent is able to perform a role of an intermediary between, on the one hand, a supply set of locations for accommodating firms and, on the other, a demand set of firms looking for locations to accommodate their activities. Eventual value judgments V relate to a comparison between performances offered and performances required which the agent derives through a series of steps, including judgments:

f - performances demanded on relevant criteria,

g - performance supplied on the same criteria,

h - match between supply and demand on these criteria, and

r - overall suitability of the location for the firm.

Functions *f*, *g* and *h* are generally based on the expert knowledge accumulated in the practices of real estate agents and they represent non-compensatory relationships. By contrast, function *r* relates to a decision rule, and in many cases it is defined as some weighted average function, representing compensatory decision making. In addition, by deriving the supplied and demanded performances separately, and then applying the matching functions, the agent is able to take overperformance as well as underperformance into account (Arentze et al., 1996; Arentze et al., 2000).

Such a functional specification of the model allows different types of applications. The first type of application involves an individual firm looking for a satisfactory or optimal location. In this case, J=1 and the relevant matrices are collapsed into vectors. The agent then generates a set of locations meeting minimum requirements or a list of feasible locations, sorted in terms of overall value judgment/evaluation/preference.

A second type of application does not start with the firm, but rather with the location. In this case, the problem is to find the firm or set of firms which would match or be most suitable for any given location. This could be relevant for real estate brokers analyzing the market for a certain (type of) office. Technically, the matrices would again collapse into vector, but now into the other dimension.

Thirdly, the focus is also on the full matrix V in an attempt to simulate the allocation of firms, seeking a location, to the set of available locations. In principle, this mechanism could be based on any specific allocation model, based on some optimality criteria (Cromley and Hanink, 1999). In this case, the agent can be used in dynamic land use simulations, either in aggregate simulations like cellular automata (White and Engelen, 1993) or in integrated land use-transport simulations (Mackett, 1985; Timmermans, 2003) or in multi-agent simulation systems (Ma et al., 2006; Saarloos et al., 2005; Arentze and Timmermans, 2007). In the latter case, rules to specify the interactions between agents (firms) need to be defined.

3 Decision tables and expert knowledge

The agent is specified by a set of functions that can be defined by, for example, expert knowledge. One of the techniques used for capturing and storing such knowledge involves decision tables (DTs), which were used in the agent developed in this study. In general, DTs are a precise and compact way to model complicated logic through if-then-else statements which associate conditions with actions to perform. Verhelst (1980) defined DTs as:

> *… a table representing the exhaustive set of mutual exclusive conditional expressions within a pre-defined problem area*

Each decision corresponds to a variable whose possible values are listed among the condition alternatives. Each action is a procedure to perform and the entries specify whether (or in what order) the action is to be performed for the set of condition alternatives to which the entry corresponds. The DTs allow us to model the derivation of demands of a firm as well as the performance offered by locations, taking into account non-compensatory decision rules. At the same time, the DTs facilitate consistency checking and validation of the knowledge model.

Table 1 presents an example of a DT. Here we start by assessing the first condition (C1). If its value meets condition state V1a, the evaluation is done, as the remaining conditions do not require any further evaluation (represented by a blank cell). Otherwise, it meets the alternative condition state V1b and we need to evaluate the second condition (C2). Again, if it meets V2a, the evaluation is done. Otherwise, it meets V2b and we need to evaluate the third condition (C3). Having defined whether it is V3a or V3b, the evaluation of this table is completely finished. The actions A_i presented in Table 1 refer to the values that the overall evaluation will assume. This DT is exhaustive in the sense that V1a and V1b cover the complete domain of C1, and conditions V2a and V2b cover the complete domain of C2, and V3a and V3b cover the complete domain of C3. The decision rules are, at the same time, mutually exclusive as the ‘a’ and ‘b’ states are mutually exclusive for each condition variable.

C1	V1a	V1b		
C2	-	V2a	V2b	
C3	-	-	V3a	V3b
Actions	**A1**	**A2**	**A3**	**A4**

Table 1 – Example of a decision table

The DTs used in this study were constructed through a knowledge elicitation process of a group of experts in office real estate markets. It was specifically designed for modeling the related location-decision process, comprising a comprehensive set of DTs. It covers an exhaustive set of potentially relevant performance dimensions for determining the match between any given firm and office pairing. The DTs are hierarchically structured in a system through table-condition-subtable links (i.e., conditions in a main table that are operationalized in a subtable). At the highest level, the following main condition variables (or dimensions), that is aspects on which demand and supply should match, were identified as:

1. time that the property becomes available;
2. economic aspects;
3. size of the building;
4. size of the lot;
5. quality of the location;
6. quality of the building; and
7. other specific aspects.

In addition, each DT comprises two sections - for evaluating both demand and supply. This allows the definition of the functions *f* and *g* according to the functional specification discussed before. Moreover, function *h* is also modeled as a DT, combining both derived demand and supply scores through "if-then" statements. The results of the matching process are presented on a 5-point scale representing the levels of:

strong underperformance ('-2'),
underperformance ('-1'),
match ('0'),
overperformance ('+1'), and
strong overperformance ('+2').

4 Software implementation

The program provides a suitable user interface for the agent so that it can be used as a decision support tool, which has been developed in a modular fashion according to the functional specification. Each task (deriving scores for both demand and supply, determining the match between them, evaluating the match results and performing the applications) is executed through a specific module of the system, which interacts with other modules. Such interaction is based on the matrices indicated in section 2, which are technically represented as DTs (or a section of one) that are used for storing input and output data and which are responsible for the exchange of information in the tool.

The program works within a project environment that manages the data tables (mainly tab-delimited text files) and it contains references to those data files and to binary variables linked to each computational procedure that define the current status of the project (or which tasks have already been performed). Therefore, during the execution of the program, features are disabled or enabled depending on what step of an analysis the user is performing. For example, if the demand and the supply have not been scored, the matching feature will not be enabled, or if the evaluation has not been done the applications will not be enabled.

The tool has been developed as an application for *Microsoft Windows* operational systems, using the C++ programming language (in C++ Builder programming environment). Although it may be used as part of a broader planning support system and, for example, operate within a GIS environment, it is currently a standalone, under-construction program which has been built for testing purposes. In any case, the software requires the following set of inputs, which should be prepared beforehand:

1. environmental characteristics (locations), which should be integrated in a database of office locations generated through GIS facilities;
2. the firm's characteristics, which can be generated through a standard spreadsheet or by using a specific interface provided by the tool; and
3. the firm's priorities with respect to those performance characteristics which are to be used in the evaluation step.

It is then possible to start the program and perform the tasks. As explained before, the modules interact with each other in the sense that outputs from one module are used as inputs for other modules and so on.

Figure 1 describes the processes discussed above, and their inherent relationships, showing both user and computer (machine) action spaces. It also indicates the tool's architecture and related menus for a suggested graphical interface where such processes can be performed. In the current implementation, this describes a user interface, but we emphasize that implementations are only envisioned where this describes an interface of the agent for the interaction with other (computational) agents in a broader planning support system.

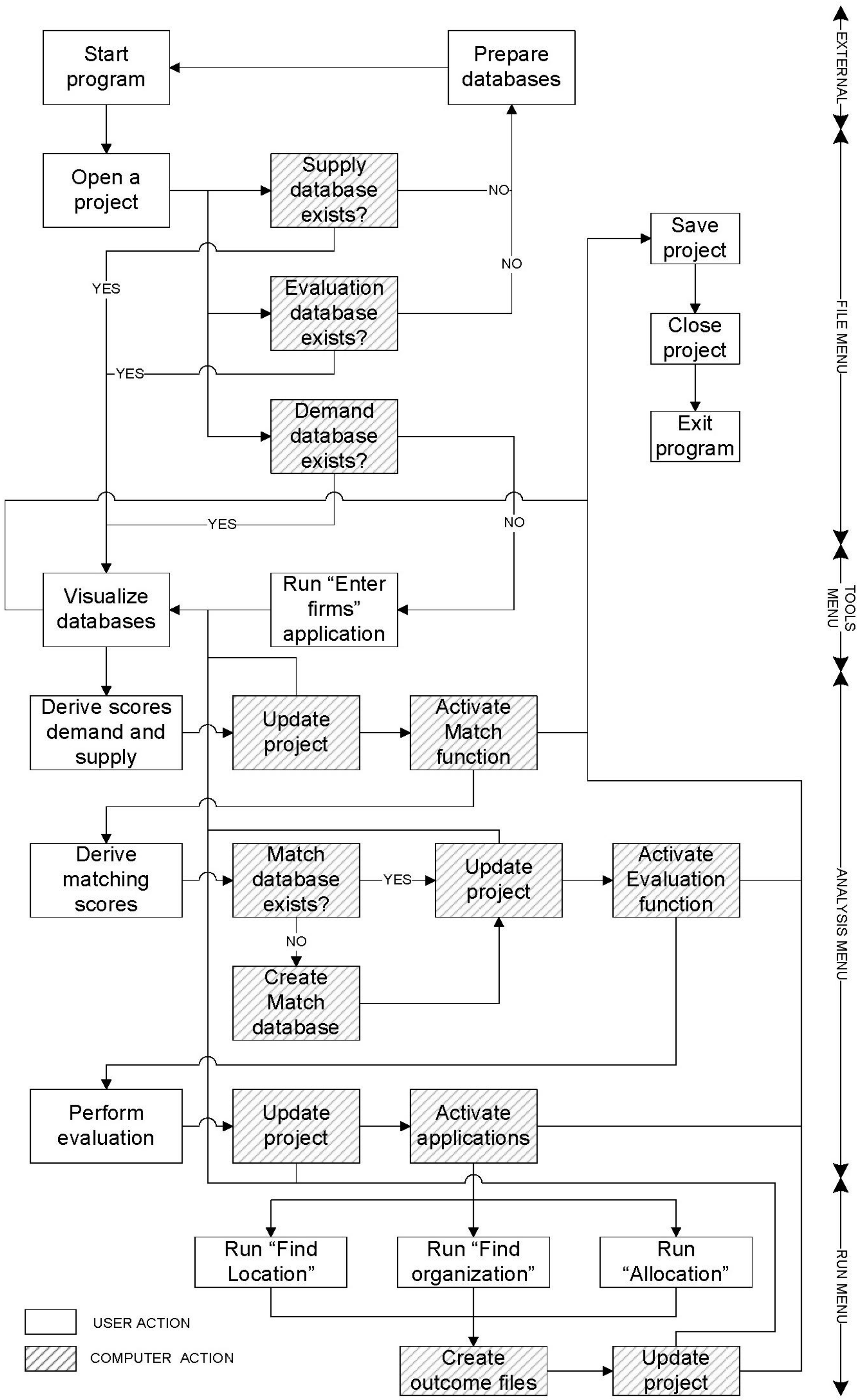

Figure 1 – The support system's architecture and inherent computational/user processes

5 Illustrations

To illustrate the decision support tool that has been developed, we carried out demonstrations of the delineation of location choice sets for some possible organization profiles in The Netherlands. Note that the current version refers to a prototype that focuses on the spatial aspect. Although there are several dimensions in the set of DTs as discussed before (time that the property becomes available, economic aspects, size of the building, size of the lot, quality of the location, quality of the building, and other specific aspects), this prototype comprises a part of the dimension 'quality of the location'. It assesses the following aspects (sub dimensions):

Geographic Location,

Proximity to Airport,

Proximity to High Speed Train (HST) station, and

Proximity to Roadway Network.

Each of these aspects consists of a specific DT or a subset of a DT which contains conditions coded as "if-then" rules.

Y_j	Description	Values	Encoding
Y1	Required type of urbanization	4 big cities Expanding city Other type of city	1 2 3
Y2	Required number of inhabitants per municipality	p > 100.000 50.000 ≤ p ≤ 100.000 p < 50.000	1 2 3
Y3	Scale of service	Local Regional National International	1 2 3 4
Y4	Required airport	YES NO	1 2
Y5	Type of required airport	Regional National	1 2
Y6	Required HST station	YES NO	1 2
Y7	No. of employees in the office	-	-
Y8	No. of employees who receive visitors	-	-
Y9	No. of visits/employee/week	-	-
Y10	No. of visitors/time	-	-
Y11	No. of visits/employee/week to external customers	-	-
Y12	Scale area where employees come from	Local Regional Higher than regional	1 2 3
Y13	% car-dependent employees	-	-
Y14	% of car-dependent employees present in the office	-	-

Table 2 – Description and encoding of demand variables

X_i	Description	Values	Encoding
X1	Type of urban area	4 big cities Expanding city Other type of city	1 2 3
X2	Population	Number of inhabitants at the municipality level	
X3	Travel time to the closest airport (any)	Euclidian distance between the location and the airport	
X4	Travel time to a large-scale international airport	Euclidian distance between the location and the airport	
X5	Travel time to the closest HST station	Euclidian distance between the location and the station	
X6	Distance to the closest roadway	Shortest Euclidian distance between the location and the roadway	
X7	Presence of an intercity train station	TRUE if the location is within 5 km of station FALSE otherwise	1 2

Table 3 – Description and encoding of supply variables

Analyzing the (sub) tables related to each mentioned aspect, we identified the conditions (variables) to be assessed for both demand and supply. Tables 2 and 3 respectively present these conditions and the corresponding values that they could assume (some of them were encoded to facilitate the calculation and representation). The conditions also refer to the related nomenclature, $\mathbf{Y}_j$ and $\mathbf{X}_i$, as used in the functional specification.

To better understand the definitions of the functions specified for the model, an example illustrating such process is presented in Tables 4 and 5. They illustrate the assessment of the aspect 'geographic location' for both the demand (*f*) and supply (*g*) function respectively and the performance scores $\mathbf{Z}_j^D$ and $\mathbf{Z}_i^S$ are also obtained. Table 6 then illustrates the specification of function *h* (the matching function), which is obtained through the related performance scores.

Required type of urbanization	4 Big cities	Expanding city	Other		
Inhabitants/municipality			>100.000	100.000 - 50.000	<50.000
Performance score	Z_j^D 1	Z_j^D 2	Z_j^D 3	Z_j^D 4	Z_j^D 5

Table 4 – Decision table for "geographic location" – demand

Type of urban area	4 Big cities	Expanding city	Other		
Population			>100.000	100.000 - 50.000	<50.000
Performance score	Z_i^S 1	Z_i^S 2	Z_i^S 3	Z_i^S 4	Z_i^S 5

Table 5 – Decision table for "geographic location" – supply

Demand performance scores	Z_j^D 1			Z_j^D 2				Z_j^D 3					Z_j^D 4				Z_j^D 5			
Supply performance scores	Z_i^S 1	Z_i^S 2	Z_i^S 3	Z_i^S 1	Z_i^S 2	Z_i^S 3	Z_i^S 4	Z_i^S 1	Z_i^S 2	Z_i^S 3	Z_i^S 4	Z_i^S 5	Z_i^S 2	Z_i^S 3	Z_i^S 4	Z_i^S 5	Z_i^S 2	Z_i^S 3	Z_i^S 4	Z_i^S 5
Matching scores (Qij)	0	-1	-2	+1	0	-1	-2	+2	+1	0	-1	-2	+2	+1	0	-1	+2	+2	+1	0

Table 6 – Decision table for “geographic location” - match

5.1 Data

As for demands, we assumed that six types of firms could produce interesting results in terms of the tool’s performance. Table 7 shows each assumed type of firm and their related, adopted values. They are imaginary and they do not have any relation with an existing firm. Regarding supply, several (real) GIS-based datasets for The Netherlands were used - highway network, location of train stations and airports and municipalities’ characteristics (population, size of the city, etc.). The information extracted and calculated from those datasets was stored in a database of office locations, which is the core of the supply dataset in that it integrates all the supply information at the 6-digit postcode level. Originally, it was obtained from the Spatial Planning Agency (Dutch Government), containing 13,485 records (offices).

ID	**1**	**2**	**3**	**4**	**5**	**6**
	Electronics industry HQ	Pharmaceutical company	Flower (export) firm	Call center / Help desk	Informatics repair firm	Small real estate agency
Y1	1	2	2	2	3	3
Y2	1	1	2	1	2	3
Y3	4	3	4	3	2	1
Y4	1	1	1	2	2	2
Y5	2	1	2	0	0	0
Y6	1	1	2	2	2	2
Y7	5000	900	400	80	10	3
Y8	1000	30	50	2	10	3
Y9	30	15	25	6	60	30
Y10	100	8	10	1	5	4
Y11	4	15	5	3	10	5
Y12	3	2	1	3	2	1
Y13	80	50	65	10	70	100
Y14	75	50	65	100	95	60

Table 7 – Demand variables for different types of firm

As an illustration, Figure 2 shows the GIS datasets used in the present work, overlaid onto the office database. Evaluation is given by the suitability scores (V_{ij}), and the function to derive it (function *r*) was obtained in the present study the pair-wise comparisons method within an Analytic Hierarchy Process (AHP) framework (Saaty, 1981). Given our illustrative purpose, the judgments involved were assumed by us (imaginary weights), mainly taking into account the firm's profile.

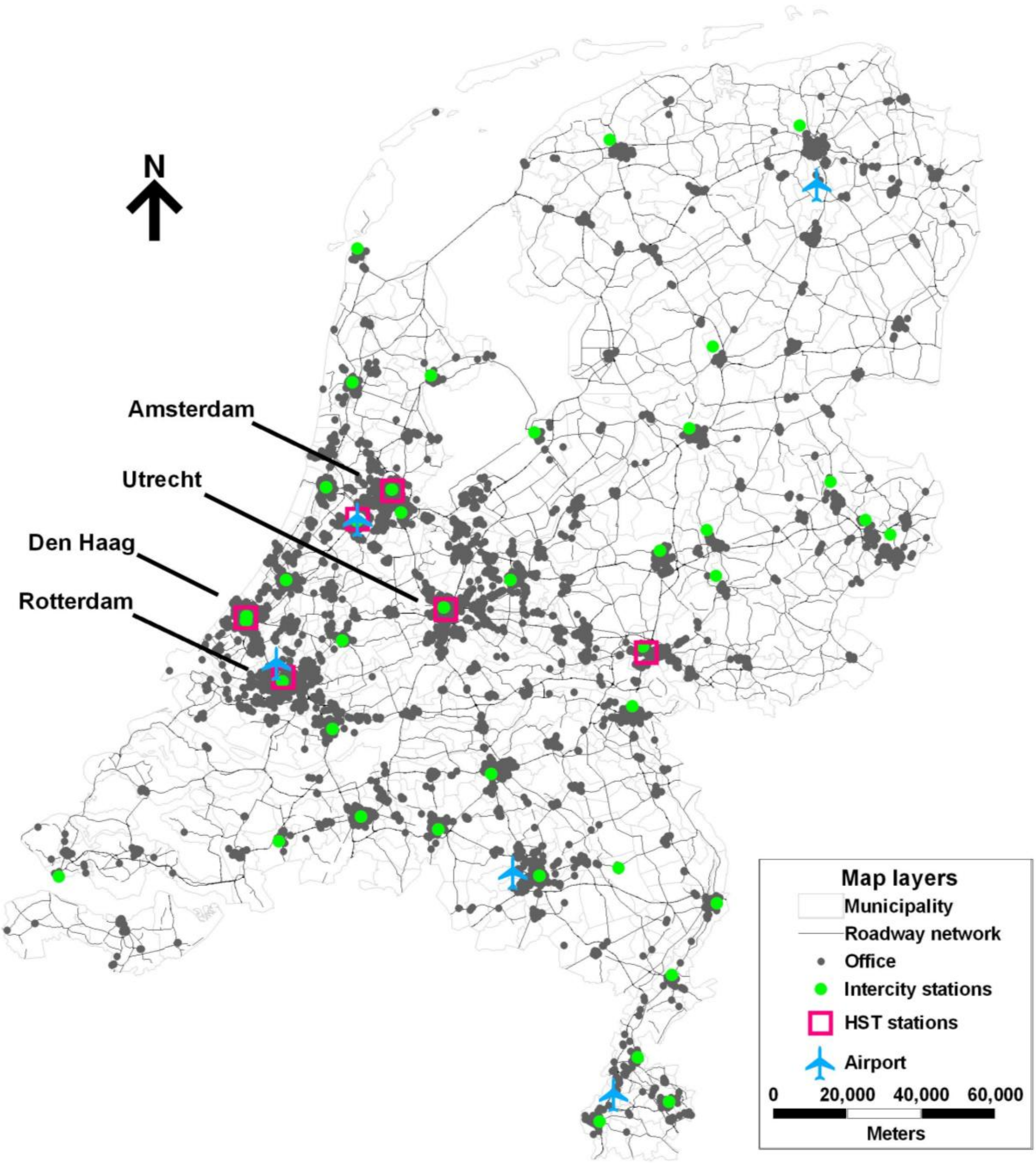

Figure 2 – Supply datasets

Table 8 shows the resulting weights for each firm on each dimension, and for each match level, on a 5-point scale. Note that the dimensions Proximity to Airport and Proximity to HST are evaluated only on a 2-point scale, i.e., -1 and 0, as this is the assumed domain in the DTs.

Firm ID	Dimension	Weight Dimension	-2	-1	0	+1	+2
1	Geographic Location	0.258	0.035	0.050	0.663	0.152	0.100
	Proximity to Airport	0.109	-	0.100	0.900	-	-
	Proximity to HST	0.069	-	0.111	0.889	-	-
	Proximity to Road	0.564	0.037	0.043	0.622	0.194	0.104
2	Geographic Location	0.342	0.044	0.046	0.579	0.197	0.134
	Proximity to Airport	0.168	-	0.100	0.900	-	-
	Proximity to HST	0.107	-	0.125	0.875	-	-
	Proximity to Road	0.383	0.050	0.057	0.609	0.174	0.110
3	Geographic Location	0.231	0.046	0.055	0.422	0.308	0.169
	Proximity to Airport	0.484	-	0.100	0.900	-	-
	Proximity to HST	0.034	-	0.667	0.333	-	-
	Proximity to Road	0.251	0.038	0.037	0.586	0.204	0.135
4	Geographic Location	0.450	0.072	0.096	0.546	0.164	0.122
	Proximity to Airport	0.050	-	0.900	0.100	-	-
	Proximity to HST	0.050	-	0.900	0.100	-	-
	Proximity to Road	0.450	0.054	0.050	0.550	0.204	0.142
5	Geographic Location	0.450	0.070	0.070	0.545	0.195	0.120
	Proximity to Airport	0.050	-	0.900	0.100	-	-
	Proximity to HST	0.050	-	0.900	0.100	-	-
	Proximity to Road	0.450	0.056	0.064	0.523	0.197	0.160
6	Geographic Location	0.450	0.082	0.087	0.427	0.254	0.150
	Proximity to Airport	0.050	-	0.900	0.100	-	-
	Proximity to HST	0.050	-	0.900	0.100	-	-
	Proximity to Road	0.450	0.056	0.061	0.506	0.198	0.179

Table 8 – Weights for each dimension, and match levels, for the Analytic Hierarchy Process-based evaluation

5.2 Results

We present the results using the mapping functions of a GIS. The overall (normalized) evaluation scores across the dimensions for each firm, are shown in the thematic maps of

Figure 3. The figures refer to the type of analysis in which suitable office locations are delineated for different sorts of firms, that is, when a firm is looking for office space.

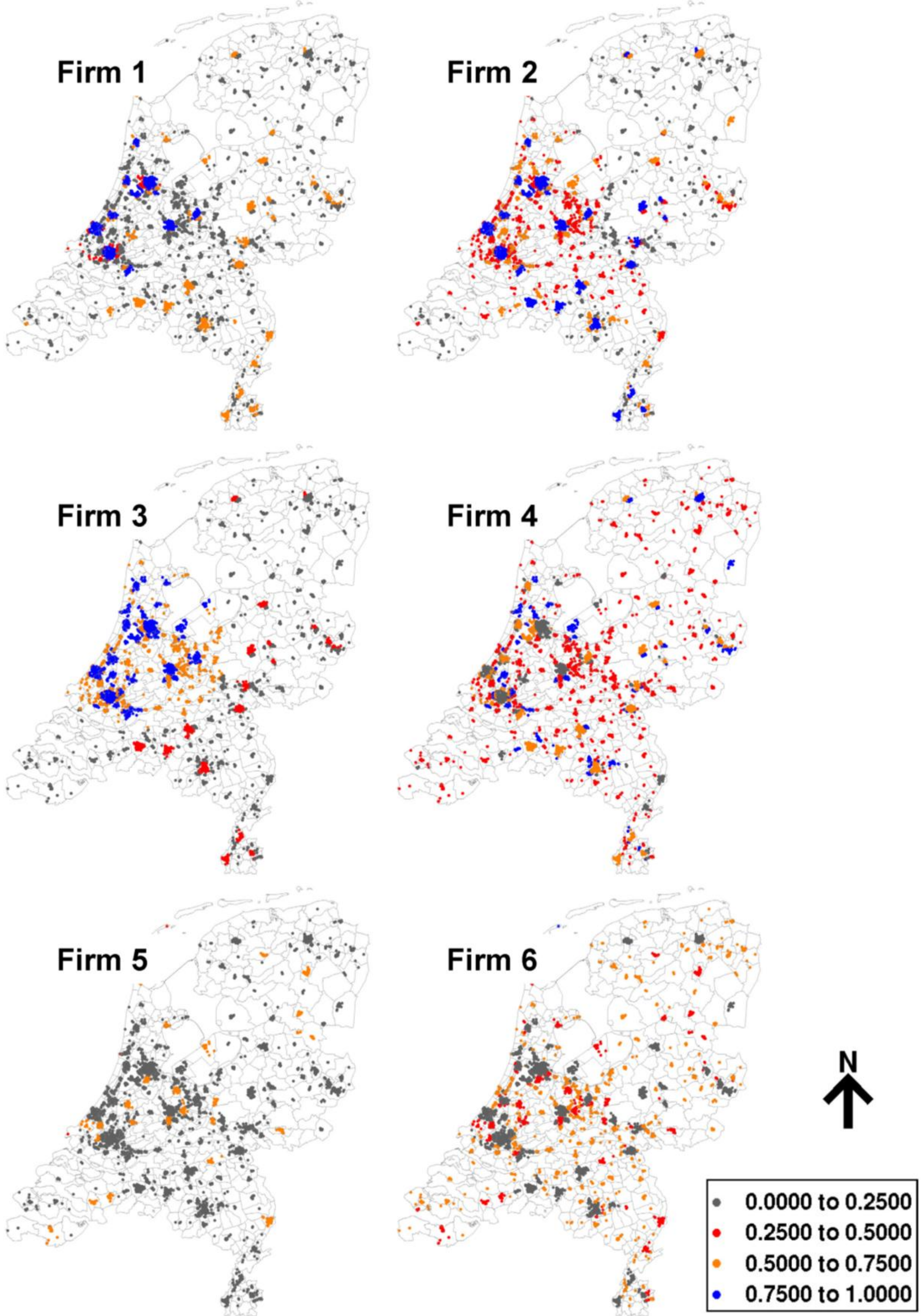

Figure 3 – Thematic maps representing the overall evaluation for Firms 1 to 6

Firm 1 is a large electronic industry and it has the highest level of requirements. Therefore, locations in Amsterdam, Den Haag, Rotterdam and Utrecht (the four big cities) have the highest scores. Locations not matching its requirements, clearly, present lower performance scores. Also, we can observe locations with lower scores (mainly between 0.25 and 0.50) surrounding places with high scores. An analysis revealed that the latter are farther from an intercity train station, which exemplifies the influence of the transportation infrastructure on location decisions. If we observe the remaining locations across the country with scores between 0.50 and 0.75, they are farther from the expected locations (i.e. one of the four big cities). However, due to the presence of an intercity train station, these locations score higher.

Results are similar for firm 2 (pharmaceutical company). Its requirements are lower than firm 1, but it still requires locations with a high level of facilities. It can be clearly identified that highly populated cities or cities in expansion have better evaluation scores.

Examining firm 3 (flower exportation company), its most important requirement is a location very close to an international airport. Therefore, the most suitable locations can be found mainly in the region of Schiphol Airport.

Analyzing now firm 4 (call center or help desk office), its requirements are lower than the previous firms. The locations with high performance scores (between 0.50 and 1.00) are mainly located outside the places meeting a high level of requirements, that is, one of the four big cities. More specifically, locations with scores between 0.50 and 0.75 match most of the requirements, except for a slight underperformance in infrastructure, referring to locations farther from the roadway network.

Firms 5 and 6 also represent a well interpretable evaluation process. Firm 5 shows the example of a small technical firm (repair of computers), with a low level of requirements. Therefore, locations in peripheral areas are selected as matching these requirements. Due to the high level of supply, we notice that there are no locations scoring very highly. Also, firm 6, representing a small real estate agency, has even lower requirements. Locations scattered across the country, mainly in smaller cities, have better evaluation scores. Similarly, they are classified within the medium-high class (between 0.50 and 0.75) and they do not score very high due to the high level of supply.

Turning to another type of analysis, we can also identify firms that would fit best in a given location, and Figure 4 illustrates this situation, where we selected the firm type with the highest evaluation score for each location. It is instructive to notice that there is a hierarchy concerning the type of firm, mainly associated with its level of requirements, and the quality of a location.

For example, locations represented in a green color are the best candidates for firm type 1. We observe that these locations offer a quality level that is in line with the level of requirements of this kind of firm. However, given that these ranking outcomes of firm types across locations are done relatively in each location, that is, the highest evaluation score in location *i*, there are few locations that do not correspond to the real level of requirements for firm type 1, such as: the (green) clusters in the north, southeast and southwest, and some scattered locations in the middle-east of the country. These locations score relatively highly for firm type 1 compared to the others, but firms of type 1 would not necessarily locate in these sites. Therefore, some caution is needed when reviewing such results.

Similarly to the above, the other firm types can be assessed according to their location. We observe that locations represented by a dark red color are the most suitable for firm type 2 - medium-sized cities which offer good transportation facilities. Locations in blue are well defined for accommodating firm type 3 (flower exportation companies), directly associated with the proximity to the international airport. Next, locations in purple would be suitable for call centers and help desk offices (type 4), locations is black would accommodate firm type 5, and locations in pink would fit firm type 6.

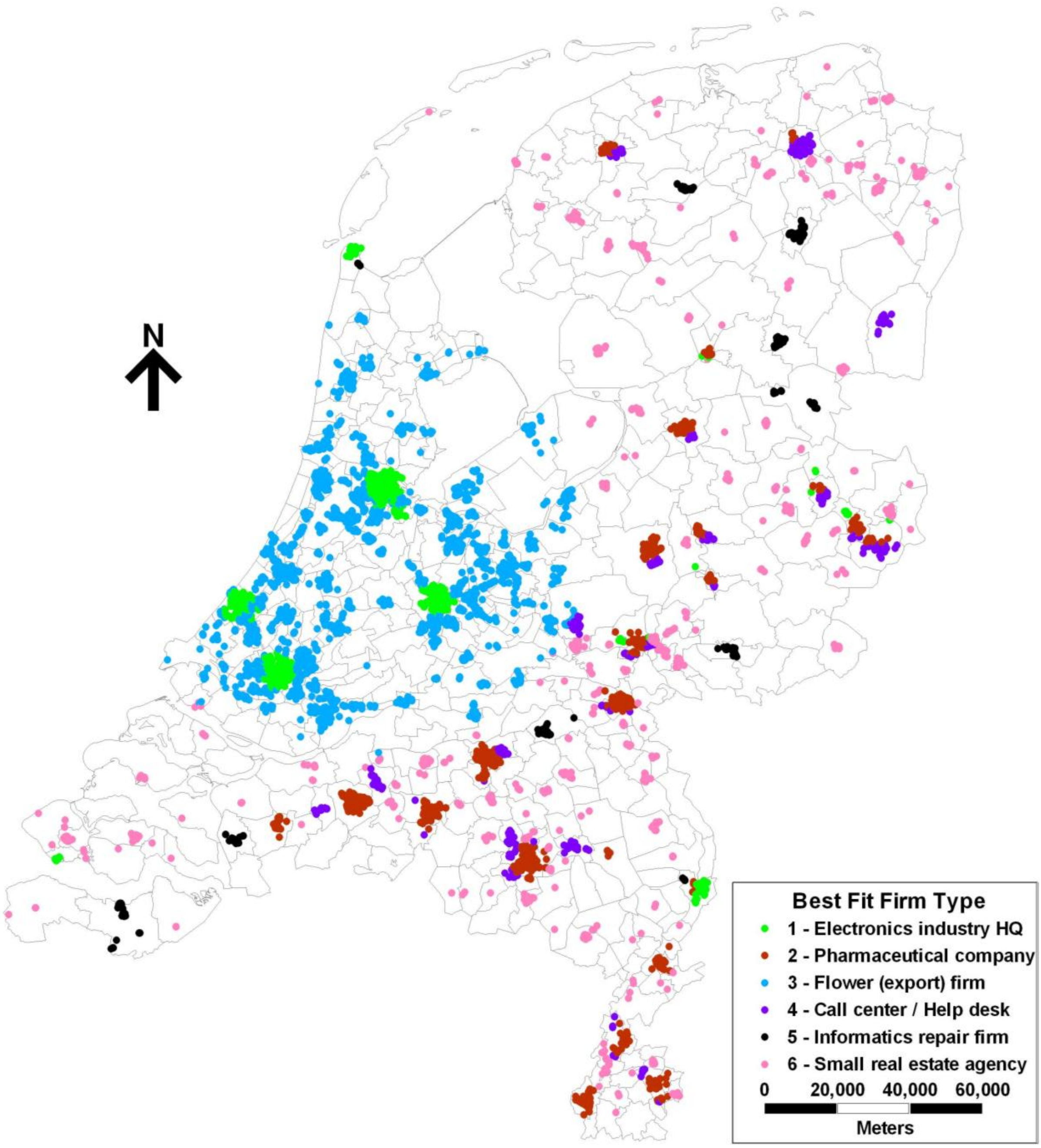

Figure 4 – Thematic map representing the best-fit firm type for each office location

6 Conclusions

We have presented here the scope and the contents of a decision support tool for locating office firms. Expert knowledge about office location decisions stored in DTs is the basis for deriving several types of functions and such knowledge consists of numerous aspects. Although the implementation of the tool developed here comprises only the aspects related to the quality of a location that firms consider, we reached some interesting conclusions from the obtained results.

Firstly, the way that the tool has been developed reflects the functional specification of the model, following the steps of deriving performance scores for both the demand and supply sides separately, computing the matching scores between them and performing some type of evaluation. It generates a very flexible and modular approach that allows:

1. verification and control of the outcomes in each step, and
2. inclusion and implementation of other relevant aspects related to the location decision processes of office firms.

In addition, the evaluation process at this current version is based on the method of pair-wise comparisons in the framework of the Analytic Hierarchy Process (AHP). However, it is important to remember that other methods for evaluating the matching scores can be adopted and implemented. Furthermore, although consisting of only a part of the dimensions related to the quality of the location, the tool displays plausible behavior when tested with different sets of demands. It allows the delineation of suitable location choice sets for each one of those sets of demands in an early site-suitability analysis. Nevertheless, further studies will be carried out, developing an extension of the tool to include a full set of dimensions.

Secondly, one particular point of attention concerns the way the proposed model deals with financial costs aspects. Although land or floor space rent prices are not explicitly considered, costs are taken into account by means of the overperformance concept. Overperformance generally means that more quality is offered than is needed against a price determined by the market. Hence, the cost aspect is captured in the evaluation phase, when an overperformance in one dimension is assessed negatively. Note that, the availability of office space was not taken into account at this stage, as our focus was on the development of a prototype to assess the quality of the location at a regional level. However, such related aspects shall be developed, and this should result in a more realistic model for site-suitability analyses of office firms. The use of real datasets showing firm's preferences is also another issue to be considered in order to improve the model.

Finally, apart from the delineation of location-choice sets for a firm seeking a location, this design of the system also allows users to find firms that meet the characteristics of a given location. Furthermore, the agent supports the more generic problem of determining the allocation of a set of firms to a set of vacant locations. This application involves an iterative process which attempts to maximize an overall system result given the matching between locations and firms, based on the evaluation scores.

In sum, since these features allow inclusion of domain knowledge, and they contain a set of concepts and mechanisms to support and simulate location decisions, they can be useful in decision making processes related to real estate and land development as well as urban and regional planning.

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