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CISEPO (CITY SELECTION PROGRAM): A DSS FOR RELOCATING COMPANIES WITHIN THE U.S.

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ABSTRACT. *The aim of this paper is to design a decision support system that allows companies to consider their options with respect to relocation within the United States. A prototype system is developed through a rigorous development methodology and illustrates a style of development that attempts to ensure system maintainability, correctness, consistency of deduction and promotes quality software. The system utilizes data that allows a hybrid information systems to be created that combines artificial intelligence and spreadsheet techniques. The system allows individual companies to examine their relocation needs and opportunities while also acting as an educational tool for business and planning students.*

INTRODUCTION

The nature of the competitive global market has placed an emphasis upon return for investment in all aspects of a corporation's business endeavors. This emphasis is no longer limited to the factory floor or the retail market sector of a companies operations, but now pervades every aspect of a business, none more so than that of the work force. This has lead companies to assess the effectiveness and efficiency of their employees and the location of their plants in respect to the returns that could be obtained elsewhere. Thus, for the first time American companies are relocating and moving to sites that will give their companies advantage — in some cases this may involve moving from their historical homes to sites where the work force and economic conditions offer the companies significant benefits.

In this paper we show a means by which a company can, through the creation of a company profile, be contrasted against profiles of 50 cities in the United States, and a match can be made such that the city which best facilitates the company's needs is identified. The mechanism through which this is achieved is that of a knowledge-based decision support system used in conjunction with a spreadsheet and run upon a micro-computer.

The advantages of Decision Support Systems (DSS) are such that they provide a source of expertise when not otherwise available, standardize deductions, and act as a uniform repository of knowledge that can be updated in line with emerging or new techniques. These and other

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advantages have been extensively documented in the DSS literature (Keen & Mortin, 1976; Alter, 1980; Turban, 1984).

OVERVIEW OF THE RELOCATION DOMAIN PARAMETERS

The managers of today's corporations and companies are faced with many problems, none more pressing than the need for motivated, skilled and efficient workers, the supply of which is projected to fall dramatically in the 1990s (the post-baby boom era.) To further complicate this problem, the companies face severe socio-economic pressures in many parts of the country in attempting to attract workers to their areas. This is especially true in the large metropolitan areas such as Southern California and New York, where quality housing, schooling, and other life style factors required by workers are prohibitory in expense. These factors have therefore lead many organizations to consider their location as a limiting factor in their growth and future profitability and, as a consequence, have considered the necessity to relocate in order to grow as a corporate entity, if not just to survive.

Researchers in urban science and industrial location theory have identified factors such as: transportation, topology, resources, market access, labor availability, taxes, and climate as influencing the decision to relocate an organization (Miller, 1982). These factors, which are all variable in terms of their geographic position and all have a direct impact upon production costs and the ability to produce a product in one location cheaper than at another, can have a significant influence upon a company's profitability if not survival (Toyne, 1974).

This paper describes a computer system, CISEPO (City Selection Program), that is designed to assist managers in their decision to relocate. The primary objective of the system is to provide managers with the selection of a new possible corporate site according to the profile of the company. In order to achieve this, the system analyzes 50 of the major cities in the United States and measures their attributes against those that describe the company under consideration before selecting a city that best fits the corporation's needs. After a city has been selected, the program displays a brief description of its selection and the average values for all considered alternatives, allowing a comparison to be made.

SYSTEM SPECIFICATION

In order for the city selection program to determine suitable cities for a corporation to relocate, three types of knowledge are required: city profiles, a company profile, and knowledge on how to select a city that best fits the company profile.

A study by Sellers and Michels (Sellers & Michels, 1990, October) drew together data that classifies 50 cities according to a variety of factors that experts and managers agreed to be the most important ones when selecting a company site. In their study, the top ten sites were selected for a generic company, based upon the ranking of cities by experts. The study in this paper goes further in that the city profiles are examined for suitability for relocating a particular company as described by the system user, and so the city selected may be different every time depending upon the requirements of the organization.

SYSTEM DEVELOPMENT

The development of the DSS followed a methodology that attempted to promote rigor and accountability into the creation process (Plant, 1991). The methodology can be simplified as follows (see Figure 1):

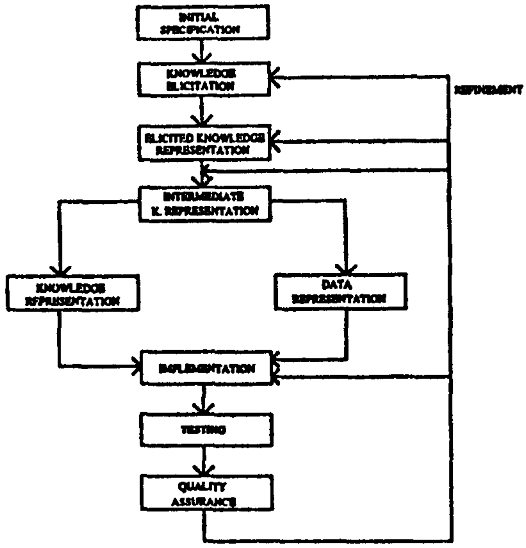

FIGURE 1. Development Methodology.

The knowledge engineer commences with a specification of the system's requirements. This is termed the initial specification because it is extremely difficult to fully specify knowledge-based systems in a formal manner. Thus, the developer attempts to create as rigorous specification as possible, in the style described and presented in the previous section. This specification is then used as a basis from which to proceed in system development. Its main functions are to define the boundaries of the system's domain, both in terms of breadth and depth, while acting as a baseline document so that the system developed can be compared against the initial specification requirements.

Having specified the system, the knowledge engineer then proceeds to select an elicitation technique (Burton, Shadbolt, Hedgecock, & Rugg, 1987) and extract the domain specific knowledge from the domain expert or knowledge source. The elicited knowledge is usually in the form of text, such as a transcribed interview, and this is known as the elicited knowledge representation. The third stage is to analyze the elicited knowledge, a process known as knowledge acquisition (Wlebank, 1983), the aim of which is to refine the knowledge and identify inconsistencies, incompleteness, or areas that need clarifying. The process may utilize intermediate representations with which to add structure to the knowledge, e.g., decision tables or trees. The intermediate form allows the knowledge to select a representation, e.g., rules (Waterman, 1986), with which to implement the system. Finally, system testing and quality assurance measures can be performed. The step-wise development with multiple implementation independent stages allows for errors to be easily corrected and gaps in the knowledge to be filled with consistency.

We will now consider each of these stages in the development of the relocation decision support system.

Knowledge Elicitation

Knowledge elicitation is a process in which the domain knowledge is extracted from a domain expert or other sources and organized into a form that can subsequently be analyzed and used in the knowledge representation process. Several techniques are available to the knowledge engineer including reporting, interviewing, and literature referral (Weilinga & Breuker, 1985).

The knowledge elicitation processes used in this study included the utilization of literature-based sources of expert knowledge. This simulated the use of multiple experts, an acknowledged benefit in insuring consistency, correctness, and completeness (Mittal & Dym, 1985).

The knowledge elicitation literature was divided into two types: primary knowledge sources and secondary knowledge sources. The primary sources were classified as those that provided data on explicit parameters that would be of relevance to a decision of whether a company would wish to relocate to that site. These included such data as: SAT scores, mean salaries, and skills available at that location. The secondary knowledge sources were those that were influential in how a parameter would be weighed against the other parameters, e.g., is it more important to have an educated work force or a low white collar salary, and in what proportion? The primary sources of data were, for example, Fortune's survey of American cities (Sellers, October, 1990) and the cost-of-living index for American cities (American Chamber of Commerce Research Associates, 1991). The texts on economic, scientific, and industrial geography acted as the basis for the weighing multipliers that were associated to the parameters (Erickson & Wasylenko, 1980; Lloyd & Dicken, 1977; Haggett, Cliff, & Frey, 1977).

Knowledge Acquisition: Developing the Representations

The result of the knowledge elicitation phase is a raw elicited representation of the form:

City = Salt Lake City, Utah
Population 1990 = 1,089,388
Population Growth 1990-1995 = 6%
Unemployment 1989 = 4.5%
Average ACT Score: City = 19.5
Average ACT Score: Suburban = 21.3
Average Salary 1987: Manufacturing = $23,340
Average Salary 1987: White Collar = $19,016
Labor Market Stress Index = 107
Cost-of-living Index = 93.8

City = Austin, Texas
Population 1990 = 787,360
Population Growth 1990-1995 = 12%
Unemployment 1989 = 5.4%
Average SAT Score: City = 930
Average SAT Score: Suburban = 983
Average Salary 1987: Manufacturing = $25,884
Average Salary 1987: White Collar = $20,585
Labor Market Stress Index = 80
Cost-of-living Index = 99.2

The major data consideration was that of the information required to create the city profiles. In all, 50 cities were utilized with the profile for each city being based upon nine variables: population, population growth rate, unemployment rate, average SAT & ACT scores for the city and the suburbs, average salaries for manufacturing and white collar employees, the labor stress index (LSI), and the cost-of-living index (CLI). The labor stress index, created by Sellers et al. (1990, October), is derived by "tracking unemployment, changes in annual wages, and unemployment growth versus expansion of the local labor pool since 1984" while the cost-of-living index, devised by the American Chamber of Commerce Researchers Association (1991), is used to equate salaries in different cities. For example the equation:

$$(\text{Index\#}_1/\text{Index\#}_2) * \text{Salary}$$

will give us the equivalent salary in city$\#_2$ to that of city$\#_1$:

$$\text{City\#}_1/\text{City\#}_2$$

Thus to find the St. Louis equivalent of a $25,000 salary in Philadelphia, we take the equation:

$$\text{City\#}_1/\text{City\#}_2 \quad (\text{Index\#}_1/\text{Index\#}_2) * \text{Salary} = \$\_\_\_\_\_\_\_\_\_\_\_\_$$

and deuce:

St. Louis/Philadelphia (98.8/128.7) * $25,000 = $19,192

while the Philadelphia equivalent of a $25,000 salary in St. Louis is:

Philadelphia/St. Louis (128.7/98.8) * $25,000 = $32,566

from which we can see that costs in terms of salaries alone are an important issue for a company to consider.

The creation of the city profile data base had two major problems: it's always changing and, as originally stated, it's not possible to compare among its different variables. The first of these problems was solved by using a readily available and easy-to-use tool to implement the database: a QUATTRO spreadsheet. The second problem encountered with the city profile database was how to compare one variable against the other, how to equate population against average manufacturing salary, for example. To overcome this, the database was transformed into a common notation to allow the comparison of different fields. This was achieved through the translation of each variable of each city into the number of standard deviations the city moves away from the mean for that variable for the entire database. In order to do this, we need to compute the average and standard deviation of each variable of the database. Then, the absolute value of each variable of each city is subtracted from the average of that variable for the database. The result is then divided by the standard deviation obtained for that variable, and a new set of figures is obtained that allow the user to compare a city for any variable, the figures themselves being computed in the QUATTRO spreadsheet. Details are given in Tables 1 and 2.

After the database of values for the cities was created, the next stage was selecting from these cities a city that best fits the company description. The first step towards this was determining the company profile. The parameters for which were: company type, company size, life stage, and skill requirements.

The company type was divided up into three alternatives: manufacturing, administrative, or both since some companies are exclusively administrative in nature, such as accounting firms, while others are primarily manufacturing in nature, and the administrative part of the company's process is not a significant part of its production, e.g., textile manufacture or assembly operations. The third type of company entails both an administrative sector and a manufacturing sector; an example of this is high-tech manufacturing, where the research and development team is as important as the manufacturing group.

The second parameter in the company profile is that of company size. Again, this is divided into three categories according to the number of employees. The three categories are: 0 to 50, 51 to 100, and 101 or more.

TABLE 1. Cities Database in Absolute Values

City	Populat.	Growth	Unempl	ACT		SAT		Average Salaries		LMSI
				City	Suburbs	City	Suburbs	Manufac.	W.Collar	
Albany, New York	856,466	2%	4.2%	0.0	0.0	956	1,056	$25,219	$21,284	93
Atlanta	2,872,060	13%	5.1%	0.0	0.0	728	900	$25,795	$27,242	100
Austin	787,360	12%	5.4%	0.0	0.0	930	983	$25,884	$20,585	80
Baltimore	2,389,385	5%	4.0%	0.0	0.0	754	945	$27,369	$25,381	100
Birmingham, Alabama	931,129	2%	5.7%	16.4	22.0	0	0	$21,719	$22,437	113
Boston	2,848,981	0%	3.4%	0.0	0.0	764	998	$28,176	$28,589	120
Buffalo	949,293	-3%	5.8%	0.0	0.0	969	969	$26,814	$23,209	87
Charlotte, N.Carolina	1,147,393	8%	3.2%	0.0	0.0	865	792	$21,177	$24,673	113
Chicago	6,259,615	1%	5.5%	13.6	21.4	0	0	$27,204	$30,229	107
Cincinnati	1,469,493	3%	4.5%	0.0	0.0	879	996	$29,857	$22,122	107
Cleveland	1,842,553	-2%	4.8%	0.0	0.0	739	966	$28,641	$22,923	107
Columbus	1,375,997	6%	4.8%	0.0	0.0	940	1,002	$27,509	$21,454	100
Dallas/Fort Worth	3,923,388	11%	5.5%	0.0	0.0	794	963	$27,450	$26,237	100
Dayton	958,196	2%	5.1%	0.0	0.0	962	1,007	$29,022	$20,020	93
Denver	1,656,279	3%	5.4%	0.0	0.0	928	976	$29,660	$27,112	93
Detroit	4,359,173	0%	7.1%	12.8	19.9	0	0	$33,935	$24,066	93
Greensboro, N.Carolina	943,916	5%	3.3%	0.0	0.0	854	855	$21,293	$20,203	107
Hartford	764,054	3%	3.3%	0.0	0.0	701	911	$28,719	$25,552	113
Houston	3,260,646	2%	5.9%	0.0	0.0	855	955	$30,795	$28,870	107
Indianapolis	1,261,073	5%	3.9%	0.0	0.0	876	936	$28,757	$22,940	120
Jacksonville	941,485	12%	5.7%	0.0	0.0	901	901	$22,083	$24,647	87
Kansas City, Missouri	1,612,035	6%	4.9%	14.1	22.0	0	0	$26,766	$25,210	107
Los Angeles	8,904,692	9%	4.7%	0.0	0.0	817	927	$26,445	$27,968	100
Louisville, Kentuky	968,758	0%	5.5%	17.2	19.9	0	0	$27,519	$21,878	100
Memphis	996,323	5%	4.7%	14.9	21.1	0	0	$21,766	$25,966	80
Miami, Florida	1,854,157	6%	6.4%	0.0	0.0	843	843	$17,827	$24,278	80
Milwaukee	1,401,580	1%	3.8%	16.6	20.8	0	0	$27,390	$24,139	113
Minneapolis/St.Paul	2,462,207	8%	3.8%	20.4	21.8	0	0	$29,823	$25,448	107
Nashville	1,005,609	9%	3.8%	17.3	19.2	0	0	$23,190	$23,131	107
New Orleans	1,294,884	-3%	7.1%	13.8	18.8	0	0	$26,662	$22,238	80
New York City	8,630,058	1%	5.4%	0.0	0.0	788	940	$26,817	$41,420	100
Norfolk, Virginia	1,430,506	10%	4.6%	0.0	0.0	907	868	$24,318	$19,514	73
Oklahoma City	961,034	-1%	4.6%	15.0	21.0	0	0	$28,008	$21,142	80
Orlando, Florida	1,034,086	17%	5.1%	0.0	0.0	893	920	$24,913	$22,509	93
Philadelphia	4,982,607	3%	3.8%	0.0	0.0	779	941	$26,885	$25,870	107
Phoenix	2,130,850	14%	4.3%	0.0	0.0	944	992	$26,475	$24,403	93
Pittsburgh	2,065,074	-4%	4.6%	0.0	0.0	839	990	$29,399	$23,475	100
Portland, Oregon	1,226,733	7%	4.5%	0.0	0.0	915	968	$25,433	$22,044	120
Richmond	864,592	7%	3.6%	0.0	0.0	762	929	$29,356	$24,285	107
Rochester, New York	980,221	0%	4.2%	0.0	0.0	817	997	$31,071	$22,886	100
Sacramento	1,460,724	14%	4.9%	0.0	0.0	949	960	$25,513	$23,867	100
Salt Lake City	1,089,388	6%	4.5%	19.5	21.3	0	0	$23,340	$19,016	107
St. Louis	2,489,411	2%	5.5%	0.0	0.0	789	1,023	$29,459	$23,366	93
San Antonio	1,368,438	9%	7.3%	0.0	0.0	743	910	$20,298	$22,771	73
San Diego	2,508,993	15%	3.9%	0.0	0.0	904	955	$26,954	$26,475	100
San Francisco Bay Area	5,165,572	6%	3.3%	0.0	0.0	855	958	$29,124	$31,810	107
Seattle	1,948,378	11%	4.6%	0.0	0.0	944	980	$31,605	$24,975	113
Tampa	2,079,323	11%	5.0%	0.0	0.0	904	899	$21,930	$22,934	87
Washington D.C.	3,860,717	9%	2.7%	0.0	0.0	707	982	$27,921	$24,888	120
West Palm Beach, FL	873,202	17%	6.0%	0.0	0.0	886	886	$31,346	$24,792	87
Average	2,188,962	6%	4.77%	16.0	20.8	852	947	$26,693	$24,449	99
Standar Deviation	1,831,390	5%	1.03%	7	9	370	407	3,250	3,579	12

The third parameter is what can be termed "life stage," that is the stage in the evolution of a company that the individual company for which the profile is being created has reached: New, for new companies, Growing, for already established companies that are expected to grow in the future, and Mature, for established firms where, due to market conditions, the firm is not expected to grow or diminish much further.

The fourth and final parameter is that of skill requirements. This covers the skill levels required by the employees to adequately perform their function within the organization. This level can be one of three levels: Lower, Normal, or Higher.

Having created a basis for the construction of a company profile, we now consider the third component of our system: The method for comparing different fields from the city profile database against the company profile. The approach taken was to assign weights to the vari-

TABLE 2. In Number of Standard Deviations from the Mean

City	Populat.	Growth	Unempl	ACT/SAT City *	ACT/SAT Suburbs *	Average Salaries Manufac.	Average Salaries W.Collar	LMSI
Albany, New York	(0.73)	(0.69)	(0.56)	0.28	0.27	(0.45)	(0.88)	(0.53)
Atlanta	0.37	1.37	0.32	(0.34)	(0.12)	(0.28)	0.78	0.04
Austin	(0.77)	1.19	0.61	0.21	0.09	(0.25)	(1.08)	(1.59)
Baltimore	0.11	(0.13)	(0.75)	(0.27)	(0.00)	0.21	0.26	0.04
Birmingham, Alabama	(0.69)	(0.69)	0.90	0.06	0.14	(1.53)	(0.56)	1.10
Boston	0.36	(1.07)	(1.34)	(0.24)	0.13	0.46	1.16	1.68
Buffalo	(0.68)	(1.63)	1.00	0.32	0.05	0.04	(0.35)	(1.02)
Charlotte, N.Carolina	(0.57)	0.43	(1.53)	0.03	(0.38)	(1.70)	0.06	1.10
Chicago	2.22	(0.88)	0.71	(0.34)	0.07	0.16	1.61	0.61
Cincinnati	(0.39)	(0.51)	(0.27)	0.07	0.12	0.97	(0.65)	0.61
Cleveland	(0.19)	(1.45)	0.03	(0.31)	0.05	0.60	(0.43)	0.61
Columbus	(0.44)	0.06	0.03	0.24	0.14	0.25	(0.84)	0.04
Dallas/Fort Worth	0.95	0.90	0.71	(0.16)	0.04	0.23	0.50	0.04
Dayton	(0.67)	(0.69)	0.32	0.30	0.15	0.72	(1.24)	(0.53)
Denver	(0.29)	(0.51)	0.61	0.21	0.07	0.91	0.74	(0.53)
Detroit	1.19	(1.07)	2.26	(0.46)	(0.10)	2.23	(0.11)	(0.53)
Greensboro, N.Carolina	(0.68)	(0.13)	(1.43)	0.01	(0.23)	(1.66)	(1.19)	0.61
Hartford	(0.78)	(0.51)	(1.43)	(0.41)	(0.09)	0.62	0.31	1.10
Houston	0.59	(0.69)	1.10	0.01	0.02	1.26	1.23	0.61
Indianapolis	(0.51)	(0.13)	(0.85)	0.06	(0.03)	0.64	(0.42)	1.68
Jacksonville	(0.68)	1.19	0.90	0.13	(0.11)	(1.42)	0.06	(1.02)
Kansas City, Missouri	(0.32)	0.06	0.12	(0.27)	0.14	0.02	0.21	0.61
Los Angeles	3.67	0.62	(0.07)	(0.09)	(0.05)	(0.08)	0.98	0.04
Louisville, Kentuky	(0.67)	(1.07)	0.71	0.18	(0.10)	0.25	(0.72)	0.04
Memphis	(0.65)	(0.13)	(0.07)	(0.15)	0.04	(1.52)	0.42	(1.59)
Miami, Florida	(0.18)	0.06	1.58	(0.02)	(0.26)	(2.73)	(0.05)	(1.59)
Milwaukee	(0.43)	(0.88)	(0.95)	0.09	0.00	0.21	(0.09)	1.10
Minneapolis/St.Paul	0.15	0.43	(0.95)	0.64	0.12	0.96	0.28	0.61
Nashville	(0.65)	0.62	(0.95)	0.19	(0.18)	(1.08)	(0.37)	0.61
New Orleans	(0.49)	(1.63)	2.26	(0.31)	(0.22)	(0.01)	(0.62)	(1.59)
New York City	3.52	(0.88)	0.61	(0.17)	(0.02)	0.04	4.74	0.04
Norfolk, Virginia	(0.41)	0.81	(0.17)	0.15	(0.19)	(0.73)	(1.38)	(2.16)
Oklahoma City	(0.67)	(1.26)	(0.17)	(0.14)	0.03	0.40	(0.92)	(1.59)
Orlando, Florida	(0.63)	2.13	0.32	0.11	(0.07)	(0.55)	(0.54)	(0.53)
Philadelphia	1.53	(0.51)	(0.95)	(0.20)	(0.01)	0.06	0.40	0.61
Phoenix	(0.03)	1.56	(0.46)	0.25	0.11	(0.07)	(0.01)	(0.53)
Pittsburgh	(0.07)	(1.82)	(0.17)	(0.04)	0.11	0.83	(0.27)	0.04
Portland, Oregon	(0.53)	0.25	(0.27)	0.17	0.05	(0.39)	(0.67)	1.68
Richmond	(0.72)	0.25	(1.14)	(0.24)	(0.04)	0.82	(0.05)	0.61
Rochester, New York	(0.66)	(1.07)	(0.56)	(0.09)	0.12	1.35	(0.44)	0.04
Sacramento	(0.40)	1.56	0.12	0.26	0.03	(0.36)	(0.16)	0.04
Salt Lake City	(0.60)	0.06	(0.27)	0.51	0.06	(1.03)	(1.52)	0.61
St. Louis	0.16	(0.69)	0.71	(0.17)	0.19	0.85	(0.30)	(0.53)
San Antonio	(0.45)	0.62	2.46	(0.29)	(0.09)	(1.97)	(0.47)	(2.16)
San Diego	0.17	1.75	(0.85)	0.14	0.02	0.08	0.57	0.04
San Francisco Bay Area	1.63	0.08	(1.43)	0.01	0.03	0.75	2.06	0.61
Seattle	(0.13)	1.00	(0.17)	0.25	0.08	1.51	0.15	1.10
Tampa	(0.06)	1.00	0.22	0.14	(0.12)	(1.47)	(0.42)	(1.02)
Washington D.C.	0.91	0.62	(2.02)	(0.39)	0.09	0.38	0.12	1.68
West Palm Beach, FL	(0.72)	2.13	1.19	0.09	(0.15)	1.43	0.10	(1.02)

* The ACT/SAT figures were calculated using either the ACT or the SAT scores, depending on data availability.

ables in the cities database, according to the profile of the company supplied by the user, the weights indicating the importance of each of the selection criteria for a given company. For example, if the company were a manufacturing firm, then we would expect the user to be more concerned with the average manufacturing salary rather than that of the white collar income. The weights (which range from 0 to 1) are multiplied against the number of standard deviations of each city, a score is computed, and the city that scores highest is selected.

It should be noted that the knowledge on city profiles is very volatile and will fluctuate with socio-economic conditions. However, the process to update the data does not require any major effort. The knowledge on how to compare the cities against a company profile does not change significantly but is the key for fine tuning the system: Different weights can be assigned to different rules, therefore adjusting the performance of the system.

Intermediate Representation: Decision Tables

As we have discussed above, the data set corresponding to a location needs to be weighted by a set of multipliers, such that the individual parameters can be used in combination. In order to do this, a set of decision tables were constructed. The decision tables were complete in coverage and thus guaranteed consistency and completeness. Further, this provided a vehicle through which the weighing could be modelled. One such table is illustrated in Table 3.

Knowledge Representation: Rules

Knowledge representation schemes describe in terms of data structures the knowledge structures used by the expert over which his deductions occur. The question of how knowledge is represented within an expert or decision support system is of central concern. This is because the structure determines the type and ease of reasoning that can occur over a given knowledge base, ultimately determining the capability of the system. A number of techniques are used to represent different knowledge types and the inter-relationships of that knowledge: (i.e., frames, semantic networks, production systems, logic; Waterman, 1986). We decided to utilize a production system architecture (Holsapple & Whinston, 1987) for our system, due in part to the following reasons: the structure of the relocation planning knowledge is suitable to being represented in a rule form; production systems are easy to implement, understand, and use; plus, the modularity of production systems provide flexibility in the development and maintenance of the knowledge base.

The knowledge base contains the rules that select an appropriate weight to be assigned to a parameter. For example, Rule 1 below corresponds to a rule from the decision table in Table 3:

RULE 1
IF Company_Size > 0 AND
Company_Size < 50
THEN Labor_Market_Stress_Index = –0.05
Unemployment_Weight = 0.05
BECAUSE
"Companies of a small size in terms of workforce
can attract recruit staff, either skilled or
unskilled, in any employment environment, or LSM index."

TABLE 3. Parameter Weighing

Company Size	0 to 50	Y		
	51 to 100		Y	
	More than 100			Y
LMSI	Total_Weight	-0.05	-0.23	-0.52
Unemployment	Total_Weight	0.05	0.23	0.52

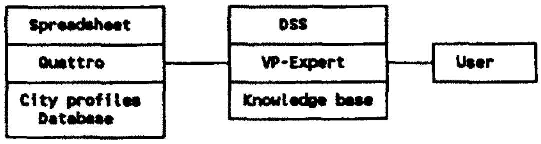

FIGURE 2. System Design.

This shows how explanations can be attached to rules, allowing the system to inform the user of the systems reasoning strategies. This is an advantage that production systems exhibit. The rule structure also allows the use of "what if" experimentation on the part of the user and allows the user to change the parameters of a problem and examine the consequences.

Implementation

The knowledge engineer, having acquired the domain knowledge and data and having represented that information in forms that would facilitate retrieval of knowledge-based decisions, could then implement the system. This was accomplished through a system with the architecture presented in Figure 2 and implemented through use of an expert system shell, VP-Expert Version 2.1 (Hicks & Lee, 1988; Pigford & Baur, 1990).

The implementation of the system was performed with system maintenance and upgrading in mind, and so extensive use of partition of both the knowledge base and database were made, thus increasing the modularity of the system. A simplified system logic, is illustrated in Figure 3.

The system logic flow chart given as Figure 3 shows how different problem types chain the system to different parts of the modularized data or knowledge base. This was found to be an effective implementation strategy which facilitated modification.

SYSTEM OPERATION

The CISEPO Decision Support System was designed to be user friendly and to require as little interaction as possible, thus enabling a wide user group to take advantage of the system and to minimize the potential for input error. After the initial introductory screens of instruction (e.g., Figure 4), the user is then asked to input data and information as the system deems necessary, such that a corporate requirements profile can be created, such as illustrated in Figure 5, which asks the user to input the skill requirements that the company requires from its workforce.

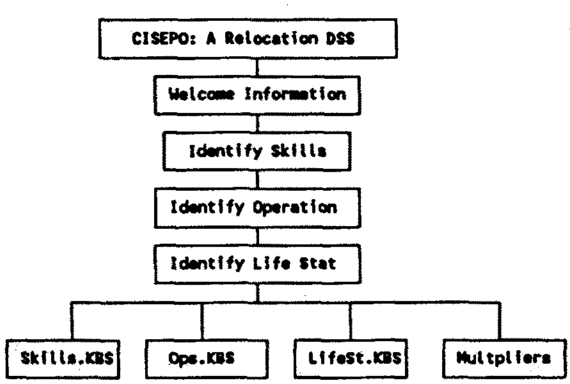

FIGURE 3. System Logic Flow Chart.

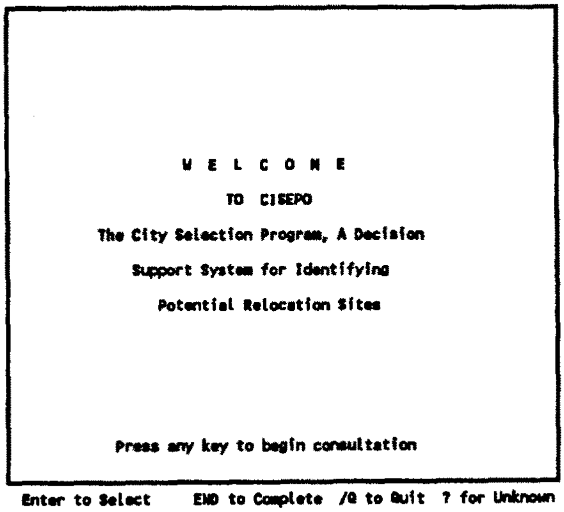

FIGURE 4. Introductory Screen.

This is followed by similar screens that require the user to input data about the company's type of operation and life stage. Figure 6 shows how the system attempts to determine if the company is primarily administrative, of a manufacturing base, or mixed in operation.

While through a screen of the type shown in Figure 7, the system attempts to determine the life stage that a company has reached. After the system has obtained sufficient information from which to determine a suitable relocation site, it then performs its analysis, the relocation-algorithm, examining the knowledge-based component. In order for the user to be aware of the systems operation, a monitor screen is displayed and constantly updated with the current city being analyzed along with the best selection so far; this is of the form illustrated in Figure 8.

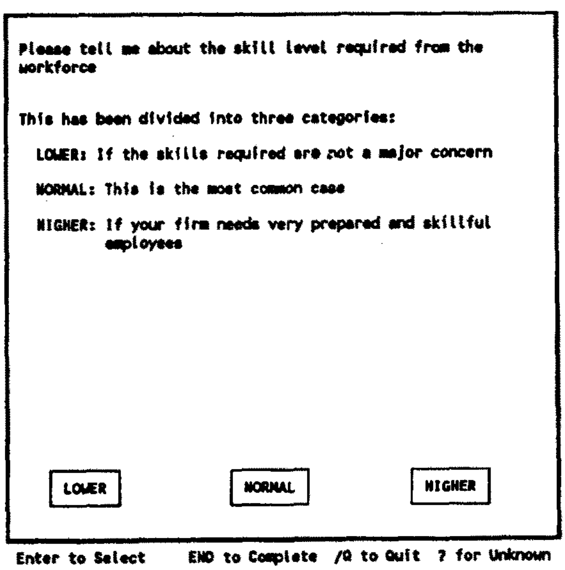

FIGURE 5. Skills Requirements Screen.

Please tell me the main type of operations of your company

This has been divided into three categories:

ADMINISTRATIVE

If your company requires mainly administrative staff

MANUFACTURING

If your company is a manufacturing firm and blue collar workers represent the vast majority of the workforce

BOTH

Your company is a manufacturing industry which needs an exceptional backing of administrative staff

[ADMINISTRATIVE] [MANUFACTURING] [BOTH]

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 6. Operational Base Screen.

At the end of this process, the city that best matches the relocation requirements for the company is displayed along with relevant details of that city. An example of such a resultant analysis is given in Figure 9.

Please tell me on which stage in life you think your company is.

It could be one of the following categories:

NEW

If the company is just starting out

GROWING

If the company has been running for some time now, but you expect to grow considerably in the future. There is still room for expansion.

MATURE

The company has been on the market for some time and expansion is negligible

[NEW] [GROWING] [MATURE]

Enter to Select END to Complete /Q to Quit ? for Unknown

FIGURE 7. Life Stage Screen.

Please wait while I search the database

Currently Analyzing: Memphis

Your Best Choice So Far: Denver

FIGURE 8. Analysis Monitor Screen.

TESTING AND QUALITY ASSURANCE

The promotion of quality in our system was a prime concern from its conception, and even though it was intended to be a prototype system, this did not give license to allow for poor design and implementation. The use of this approach increased the three major factors effecting knowledge-based system's quality that can be termed C^3: Consistency, Completeness, and Correctness. The modular approach to development in conjunction with a stringent initial specification requirement has made the prototype extremely robust within its domain parameters.

The process of validation and verification in relation to knowledge-based systems has been demonstrated to be a significant problem (O'Leary, 1988; Plant, 1990). However, the techniques used in the development of our system are such that a high level of correctness is reached. This can be justified by exhaustively showing that the systems performance matches the requirements of the decision tables, a testing mechanism that is not normally feasible to demonstrate. The subsequent successor to this system will require alternative testing techniques such as critical data testing, random data tests, or functional testing (Rushby, 1988).

For a company requiring more than 100 workers, with high skills requirements, and being a new company of an administrative operation I suggest:

Minneapolis/St. Paul

It has a population of 2,462,207 people, with an expected population growth of 7% from 1990 to 1995.
Minneapolis/St Paul has an average unemployment rate of 3.8%, and the average salaries for manufacturing and white collar workers has been estimated at $29,823 and $25,448 respectively.
The average SAT score for the suburbs is 999, and for the city 700. The labor market stress index is 107.

The Nation-wide averages are:

Population: 2,188,961 Growth: 5%
Unemployment: 4.7%
Manufacturing Average Salary: $26,692
White Collar Average Salary: $24,489
SAT City: 852 SAT Suburbs: 946
Labor Market Stress Index: 99

Press Any Key to Exit

FIGURE 9. Analysis Results Output Screen.

SUMMARY AND CONCLUSIONS

This paper has attempted to detail a prototype decision support system that assists companies to select a city within the United States for relocation purposes. The program could be adapted for any relocation problem on either an international scale or within a given urban area. The system illustrates that the techniques of artificial intelligence and spreadsheets can be combined together to produce a system that can easily be used by management or corporate planners. Further, through the use of a rigorous and structured approach to development, the system is correct, consistent, and complete for the domain covered. The system performs adequately as a prototype, with a knowledge base created from the knowledge engineer's experience and from literature. We feel that further fine tuning would be beneficial were the system to be used in a corporate environment.

The system could be enhanced by keeping a history of the cities analyzed by the system and by presenting the user with a list of top ten choices. This would then allow for other factors to be considered that are not contained within the knowledge base of our system, such as a location's proximity to transport routes or suppliers. We felt that the inclusion of these factors was beyond the scope of our study, which was designed to run upon the data of Sellers and Michels (1990, October). A paper that addresses some of these broader issues is that of Suh, Kim, and Kim (1988).

In addition to use as a corporate planning tool, the system can also be used with beneficial results as an educational tool which provokes discussion and allows theories to be examined with respect to the criteria executives use in considering corporate relocation.

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