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Is your back-up IT infrastructure in a safe location?

A multi-criteria approach to location analysis for business continuity facilities

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Abstract Building redundant capacity into an organization's information technology (IT) infrastructure is a standard part of business continuity planning (BCP). Traditionally, cost concerns have dominated the decision of where to locate the redundant facilities. However; recently managers are becoming more aware of the fact that the very issues that make the main IT facilities vulnerable to disruption (i.e. man-made or natural disasters) are likely to impact the redundant (back-up) facilities as well. This complicates the process of selecting redundant facility location(s). The problem is essentially a multi-criteria decision problem, and can be addressed using the location analysis techniques that have been used in other domains in the past. Meanwhile, what make this context somewhat unique are the decision criteria and the rather subjective nature of the decision process. This paper provides a simple decision model for the problem, and illustrates the model with a case where relevant decision criteria are identified and the solution is obtained using a mix of objective and subjective decision techniques. We believe the paper is valuable because it presents an actionable methodology for practitioners involved in BCP.

Keywords Business continuity planning · Site location decisions · Mathematical modeling · Decision support

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1 Introduction

It is well recognized in today's business world that all organizations are susceptible to risks of undesirable events that would disrupt their ongoing operations (Bryson et al. 2002). Consequently, Business Continuity Planning (BCP) is gaining more and more prominence as a strategic activity in the modern organization (Herbane et al. 2004). Although BCP has aspects that impact all functions of an organization, the most talked about domain is the information technology (IT) function for the obvious dependence of organizations on their IT infrastructure and information systems. In this respect, design of redundant IT capacity is of fundamental importance. This is a nontrivial task involving technical as well as managerial complexities.

One such complexity arises in deciding where to locate the redundant capacity. The terrorist acts of September 11, 2001, the Indian Ocean tsunami of December 26, 2004, and Hurricane Katrina of August 29, 2005, made it clear that location analysis is critical to BCP. It is unknown how many IT managers in the New Orleans area or the coastal areas of the Indian Ocean had business continuity IT facilities in 'safe locations' away from the natural disaster area. Catastrophic events such as natural disasters, terrorist attacks, and political instability reemphasize the importance of location decisions in BCP. These events have made it more obvious that locating back-up IT facilities in safe locations is almost equally important as securing the main IT infrastructure.

Location decisions have well-developed theoretical foundation (Asami and Walters 1989; Pace and Shieh 1988). They are concerned with the formulation, modeling, and solution of decision problems for identifying the optimum (or good enough) location(s) for specified facilities given a set of criteria.[1] For example, in locating simply undesirable facilities such as sewer treatment plants, the interest is in minimizing cost and exposure of city dwellers among other factors (Erkut and Neuman 1989). On the other hand, in locating a shopping mall, the objective would be maximizing accessibility while minimizing the average distance for customers in nearby cities and the cost of building and operating the facility. Since Weber (1909), a wide range of location problems such as the location of manufacturing facilities (Badri and Davis 1995; Canbolat et al. 2007), airport facilities (Min 1994), solid waste facilities (Lahdelma et al. 2002), newspaper route depots (Jacobsen and Madsen 1980), bank branches (Min 1989), motels (Kimes and Fitzsimmons 1990), fire stations and emergency response centers (Toregas et al. 1971), landfills (Cheng et al. 2003), and power plants (Barda et al. 1990; Rietveld and Ouwersloot 1992) have been studied.

Research in this area has employed a range of techniques such as integer and mixed integer formulations (Toregas et al. 1971; Cheng et al. 2003), dynamic programming (Current et al. 1990), nonlinear programming (Brimberg and Love 1995), stochastic functions (Bean et al. 1992), and heuristic and search procedures (Kuehn and Hamburger 1963).

The redundant facility location decisions are strategic, involving substantial capital investments and risks. Further, they are influenced by many qualitative (Rey et al. 1995) and quantitative factors such as economic and political conditions, and infrastructure (Canbolat et al. 2007). While qualitative factors are crucial to many location problems, they are often left out of model formulation and assumed to be management's responsibility (Lee et al. 1981). Some approaches for utilizing multiple quantitative and qualitative criteria in location problems have appeared (Badri 1996; Lee et al. 1981), but to the author's knowledge, these approaches are yet to be applied to the BCP domain. This is the point of departure for this research. This paper proposes a multi-criteria model for location decisions in (IT-focused) BCP. The approach follows a long tradition of using mathematical modeling for complex location problems (Revelle and Eiselt 2005).

The rest of the paper is organized as follows. In section 2 previous work on BCP is reviewed. Section 3 introduces the decision process model for IT backup facility location decisions, and section 4 illustrates this model by means of a case. The paper concludes with the limitations of the approach, discussion of the decision process, and implications of the study.

[1] The review here is focused on framing the context for BCP-related location decisions. For an up-to-date and more comprehensive review of international location decision models, see Revelle and Eiselt 2005.

2 Business continuity planning

Business Continuity Planning (BCP) has been receiving increasing attention in recent decades (Bell 1993; Devargas 1999; Herbane et al. 2004; Toigo 1989). There are evolving BCP methodologies aimed at assisting business managers developing effective strategies and plans. Not surprisingly, some of these have focused almost exclusively on information technology (IT) planning. For example, in 2006, the British Standards Institute published a framework to help IT planners develop effective BCP (PAS 77:2006). Other approaches to BCP have been published by the International Standards Organization (ISO), US General Accounting Office (GAO/AIMD-10.1.19), and in academic literature (Devargas 1999). In essence, all these methodologies provide a basic BCP framework involving 5 phases, and offer guidance on conducting the activities of each:

1. **Initiation:** Establish a BCP project team, and develop BCP strategic objectives. Develop master project plan with milestones, and obtain top management support.
2. **Business Impact Analysis:** Assess the potential impact of mission-critical system failures on key business processes. Assess infrastructure failure risks, and define the minimum acceptable risks for core business processes.
3. **BC Plan Development:** Identify and evaluate alternatives for BC. Select appropriate alternatives and develop implementation proposals. Obtain top management approval to develop BC infrastructure.
4. **Implementation:** Develop and document contingency plans for business continuity. Define business continuity teams and responsibilities. Define triggers for business continuity activities. Develop detailed BC procedures.
5. **Evaluation and Maintenance:** Test, and validate the BC strategy and plans. Periodically update BC strategy and plans.

The focus of this paper is the BC Plan Development phase, which is concerned with identifying alternatives and modeling risk mitigation strategies to ascertain the best possible plan for BC. Risk analysis is encouraged as a Phase 2 activity and some techniques are suggested for such analysis. Yet, no advice is given for back-up/redundant infrastructure decisions for mitigating risks. Hence, the reason for the focus on Phase 3 and particularly on location problems is that this has arguably been the most neglected activity of BCP with regards to decision aids for planners.

3 The decision model for IT back-up facility location

As many redundant capacity investments, redundant IT facilities have considerable costs that need to be justified by management. The decision process that is described below assumes that the (explicit or implicit) utility functions that management uses to assess the value of elimination (or near-elimination) of disruptions of IT operations suggest that the utility of building redundant facilities is well worth the costs. Although it is conceivable that there would be organizations—especially small to medium sized enterprises—where the costs of building such redundancy cannot be justified, for a majority of the organizations where information systems and data are mission-critical, shut-down of IT functionality is simply intolerable. In any case, since the described process includes objective (such as cost) as well as subjective (such as utility) criteria, it would still help with the (mostly implicit) justification of the investments.

Figure 1 displays the model that summarizes the basic decision process for IT redundant facilities location. As seen in the figure, this model accommodates both the objective and subjective aspects of the process (steps 4 and 5) such that they can be performed in any sequence. Because a great majority of models in the literature focus on the objective aspect of this process, the variety of objective techniques in the literature on location analysis (e.g. Brimberg and Love 1995; Cheng et al. 2003; Current et al. 1990; Kuehn and Hamburger 1963; Lahdelma et al. 2002; Toregas et al. 1971) outnumber the subjective decision techniques (Badri 1996; Lee et al. 1981).

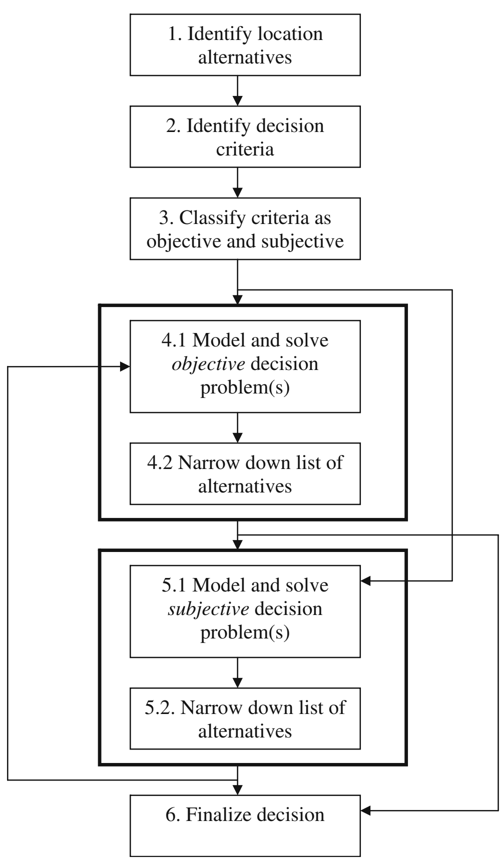

Fig. 1 The decision process

As such, the most commonly used subjective decision making technique reported in literature is Analytic Hierarchy Process (AHP) (Saaty 1980). This technique is based on obtaining decision maker input in the form of (numeric) pair-wise comparisons and calculating criterion weights from these comparisons using linear algebra. The advantage of AHP is that there are existing tools that automate the process once the decision maker input is obtained. The disadvantage, on the other hand, is the way the technique requires decision makers to indicate preferences. Expecting the decision maker to consistently indicate the importance of a decision criterion over another in numeric terms is unrealistic especially when there are a large number of criteria to be considered which would make the number of pair-wise comparisons very high. On the other hand, the qualitative discriminant process (QDP) developed by Bryson et al. (1994) does not pose such demands on the decision makers, because it requires decision maker input in the form of a simple ranked list. The QDP, as described below, was designed for ranking alternatives on multiple criteria by a group of decision makers.

3.1 The qualitative discriminant process

QDP was developed (Bryson et al. 1994; Bryson 1997) for the facilitation of multi-criteria decision making in groups. The basic premise of the approach is that many decision making scenarios (such as location decisions) go beyond objective scoring, and involve subjective judgments of various alternatives. Hence such scenarios call for the elicitation of qualitative scores from a number of decision makers. The QDP approach makes it possible to incorporate decision makers' qualitative judgments into the group decision process by allowing them to indicate their preferences in relatively "vague" terms. To be specific, the technique allows assigning a category as opposed to a point score for the alternatives being evaluated. Decision makers are expected to differentiate among alternatives at increasing levels of detail by assigning them into finer defined categories at each iteration of the preference expression process. These iterations correspond to the different qualitative criteria used in the decision making process. QDP then derives numeric estimates for these qualitative ratings. Below is a more formal summary of this two step process (Bryson 1997):

3.1.1 Qualitative rating

When qualitatively assessing the alternatives, each decision-maker in the group assigns qualitative categories C_i to each alternative such that qualitative category C_a is considered superior to C_b for each a > b. These qualitative categories are further subdivided into a set of mutually exclusive qualitative subcategories $C_{i,j}$ that are themselves divided further into a set of mutually exclusive qualitative subsubcategories $C_{i,j,k}$. This process of dividing the qualitative scale into finer defined brackets continues as many times as the number of decision criteria. The set of decision criteria as well as the number of brackets for each criterion are parameters the modeler or the group as a whole need to determine before the QDP process starts. Once this structure is established and the group has gone through a discussion of the alternatives, every individual decision maker starts assigning each decision alternative into the brackets starting with the broad categories C_i and ending up with one of the finest-defined brackets. Here, for the sake of simplicity, let's assume that there are three decision criteria hence the finest defined brackets are $C_{i,j,k}$.. Also, for non-empty brackets $C_{i,j,k}$ with two or more alternatives, the individual decision maker is required to order the alternatives using (qualitative) pairwise comparisons. Group member m's qualitative score for the N alternatives is represented by the qualitative score vector $q^m = (q_1^m, q_2^m, \ldots, q_N^m)$.

3.1.2 Derivation of numeric estimates

The qualitative scale has a corresponding numeric scale $N = (n_L, n_U)$ that consists of a set of intervals $N_i = (n_{Li}, n_{Ui})$ where N_i is equivalent to the qualitative category Ci. Likewise, for each level of qualitative subcategory, a corresponding numeric interval is defined, i.e. $N_{i,j} = (n_{L(i,j)}, n_{U(i,j)})$ corresponds to $C_{i,j}$, and $N_{i,j,k} = (n_{L(i,j,k)}, n_{U(i,j,k)})$ corresponds to $C_{i,j,k}$. Thus assignment of an alternative to a subsubcategory $C_{i,j,k}$ is equivalent to its assignment to the corresponding subsubinterval $(n_{L(i,j,k)}, n_{U(i,j,k)})$. The QDP does not require that the numeric intervals N_i be of equal length, but for a given numeric interval N_i, it is assumed that the corresponding subsubintervals $N_{i,j,k}$ are of equal length.

The QDP approach to transforming qualitative scores to numeric estimates is based on the minimum absolute deviation regression method. It creates a numeric group mean score x^{GM} that is based on individual numeric score vectors $x^m = (x_1^m, x_2^m, \ldots, x_N^m)$, which, in turn, correspond to qualitative score vectors $q^m = (q_1^m, q_2^m \ldots, q_N^m)$. This is done by solving the following optimization problem:

$$\text{Minimize} \quad \sum\nolimits_h \sum\nolimits_m \left| x_h^{GM} - x_h^m \right|$$

such that

- $n_{L(i,j,k)} <= x_h^m <= n_{U(i,j,k)}$, if alternative "$h$" was assigned to $Q_{i,j,k}$ by group member "m".
- $x_{h2}^m + \tau <= x_{h1}^m$ if alternative h_1 was ordered above h_2 by group member "m", τ being an input decision parameter that indicates the minimum numeric difference between two different values. This rule is relaxed if there are more than $\left\| l_i/_\tau \right\|$ alternatives in a narrow bracket $C_{i,j,k}$ (l_i being the length of $N_{i,j,k}$).
- $n_{L(i1,j1,k1)} <= x_h^{GM} <= n_{U(i2,j2,k2)}$ if $C_{i2,j2,k2}$ and $C_{i1,j1,k1}$ are the highest and lowest categories, respectively, to which alternative "h" was assigned.

QDP was designed to facilitate the group ranking process for a number of alternatives assuming that the relative importance of the criteria is given. However, it can just as easily be applied to the ranking of the criteria themselves hence supporting a more realistic decision scenario. The application of this slightly modified QDP procedure is illustrated in the following case.

4 Application of the model to business continuity site selection

4.1 Background on the case

The hypothetical organization in this case is The Old Europe Banking Group (OEBG); a large financial company with branches in most major cities around the world. OEBG is strategically dependent on its IT infrastructure for 24/7 global processing for its services ranging from long term financing, letters of credit to overnight loans, and transaction clearing. OEBG realized that its IT outsourcing vendor had inadequate redundant IT infrastructure that would ensure continuity of its business if there was any catastrophic system failure. After many difficulty attempts to redress the performance problems, OEBG bought out its outsourcing vendor, and started a strategic initiative to develop a stronger in-house IT organization. The first strategic move was to spin-off the IT group as a separate company 'OEBG IT Services LLC' where this spin-off would grow through acquisitions: OEBG IT Services now has four major IT centers around the world: in Mumbai, India; Markham, Ontario, Canada; Kiev, Ukraine; and London, England. Although the Kiev IT center was never established as a business continuity processing center, it is the only IT center that has all the applications that OEBG uses. The Kiev center was originally established to take advantage of low cost skills of the workforce, and to provide information processing support for the newly developing branches in Russia and other transitional economies. However, the cost/performance advantage of the Kiev center caused a greater portion of the OEBG European processes to shift from London to Kiev. Subsequently, the London and Markham centers were downsized in favor of the more cost effective centers in Kiev and India. However an audit of the IT capacity made OEBG top management concerned about: (1) the under capacity for business continuity processing; and (2) the risk exposure of the Kiev center due to rising political unrest in the Ukraine.

4.2 The IT site selection problem

OEBG formed a team to resolve the problem. After several months of work, the team obtained top management support for building three IT business continuity centers worldwide. The problem they face, however, is where in the world to locate these centers. And while this is not their decision, the team needs to provide OEBG top management the information and a process for making this difficult decision. Six locations were short-listed as good candidates (step 1 of the decision process depicted in Fig. 1) based on large and highly technical trained workforce and high quality civil infrastructure (i.e. dependable electricity, high quality telecommunication and good transportation). However four additional important factors have yet to be considered: "total cost" of starting and operating the facility, "risk of natural disasters" in the geography, "political stability" of the country, and "manageability of the local work force" (step 2 of the process in Fig. 1). Note that among these "total cost" is the only objective criterion (step 3 of the process in Fig. 1). The decision team is composed of the Manager of International Relations (MIR), the Manager for Asia Commercial Lending (MACL), and the Manager of Human Resources for Europe (MHRE), all knowledgeable about socio-economic and political conditions of the regions under consideration. The team first evaluated the 6 potential locations on the objective criteria of total cost. The mutual understanding was for the backup facilities to be in use for 5 years, therefore a 5-year planning horizon was used. For this, the decision team used the following simple formulation for calculating the total cost of a facility in each alternative country (modified from Canbolat et al., 2007) (step 4.1 of the process in Fig. 1):

$$TC = IC + LC(5\,\text{years}) = IC + L_j * \left\{(1+A_j) + (1+A_j)^2 + (1+A_j)^3 + (1+A_j)^4 + (1+A_j)^5\right\} * N$$

Where

IC is the one time investment cost,
LC is the total labor cost,
L_j is the current unit labor cost in country 'j',
A_j is the annual adjustment factor for country 'j',

and

N is total number of employees.

Also

$$A_j = i_j - e_j - p_j$$

Where

i_j is the annual inflation rate (5-year average) for country 'j',
e_j is the annual increase in exchange rate in country 'j',

and

p_j is the annual improvement in productivity (5-year average) in country 'j',

This model considers important macro-economic factors that will impact the total cost of operating facilities in different countries where the adjustment parameters, i.e. i_j, e_j, and p_j would be readily available for a decision-maker. Therefore the calculation of the total cost would be straightforward and fairly objective (although the current unit labor cost in a country may be difficult to estimate with certainty at times).

After calculating the total cost figure for each alternative location using this formulation, it was clear to the decision team that two of the alternatives would cost more than what OEBG had budgeted for this initiative. Therefore only four cost-effective and hence viable alternatives were given further consideration (step 4.2 of the process in Fig. 1). To continue with the evaluation, the team followed a multi-stage process designed based on the QDP concepts outlined in section 3.1 (step 5.1 of the process in Fig. 1):

1. Each member of the evaluation team is given the briefing files on the four locations, and is given 2 weeks for review of the files and the opportunity to do further research.
2. The team members meet and discuss the business continuity project and use QDP to evaluate the three decision criteria and then the four locations. The evaluation process takes at least three rounds.
3. After completing the rankings, the team members are encouraged to have a discussion on the outcome, and to write any comments that they feel should be included in the final report to the strategic management team.

The QDP started (Phase A) by ranking the decision criteria, i.e. "political stability" PS, "risk of natural disaster" RND, and "manageability of the local work force" MLWF.

In the first round of Phase A, the team was required to classify the criteria as "highly relevant" or "moderately relevant". In the next round, they further classified the criteria as "highly important" and "moderately important" by assigning them to the appropriate subcategories. The team members could change their preferences until each was comfortable with the ranking of his/her alternatives. If

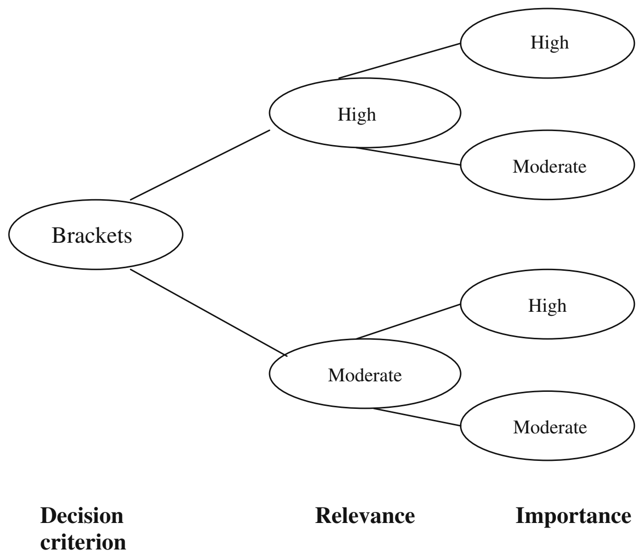

Fig. 2 The tree diagram for the categorization of criteria

more than one alternative were assigned to a narrow subcategory, pairwise comparisons were used to rank the alternatives in that subcategory. Figure 2 displays the diagram for the categorization of criteria, and Fig. 3 displays the assignments of the criteria to the subcategories and the rankings within each subcategory. Each column of the table in Fig. 3 represents the ranking of the alternatives by each decision maker with the most favorable alternative at the top. The indices i and j correspond to the values of relevance and importance for each bracket consecutively; for example, the bracket with $(i, j) = (2, 1)$ represents high relevance and low importance. The ">>" symbol means "superior to".

In order to determine the score of each criterion, a numeric range was assigned to each criterion based on relevance (High [50–100] and Moderate [0–50]). These broad brackets were further divided into two narrow ones based on importance. Note that this process results in a l_i value 25, which, in turn, results in narrow categories of [0–25], [25–50], [50–75], and [75–100]. Then the optimization problem as discussed above was modeled with the decision parameter[2] $\tau = 10$ (since no bracket includes more than $\left\| {}^{l_i}/_{\tau} \right\| \left(\left\| {}^{25}/_{10} \right\| = 2 \right)$ alternatives, the use of $\tau = 10$ is appropriate).

$$Min \sum\nolimits_{h \in \{MLWS, PS, RND\}} \sum\nolimits_{m \in \{MIR, MACL, MEHR\}} \left| x_h^{GM} - x_h^m \right|$$

st

$$\begin{aligned}
&75 <= x_{MLWF}^{MIR} <= 100, 50 <= x_{PS}^{MIR} <= 75, 25 <= x_{RND}^{MIR} <= 50,\\
&25 <= x_{MLWF}^{MACL} <= 50, 25 <= x_{PS}^{MACL} <= 50, 50 <= x_{RND}^{MACL} <= 75,\\
&50 <= x_{MLWF}^{MHRE} <= 75, 75 <= x_{PS}^{MHRE} <= 100, 75 <= x_{RND}^{MHRE} <= 100,\\
&25 <= x_{MLWF}^{GM} <= 100, 25 <= x_{PS}^{GM} <= 100, 25 <= x_{RND}^{GM} <= 100,\\
&\qquad x_{PS}^{MACL} - x_{MLWF}^{MACL} >= 10, x_{RND}^{MHRE} - x_{PS}^{MHRE} >= 10
\end{aligned}$$

(i , j)	MIR	MACL	MHRE
(2,2)	MLWF		RND>>PS
(2,1)	PS	RND	MLWF
(1,2)	RND	PS>>MLWF	
(1,1)			

Fig. 3 Rankings of decision criteria by each decision maker

Note that the upper and lower limits in the formulation of these constraints come from the decision maker preferences displayed in Fig. 3. The model solution (obtained from GAMS solver) includes the individual and group scores for each criterion and a group ranking of the criteria as seen in Fig. 4.

In phase B of the QDP, each decision maker classified alternatives[3] according to the criteria in the order that the criteria were ranked in phase A. The risk of natural disasters was determined to be the strongest criterion in phase A. Therefore, in the first round of phase B, each alternative was assigned by each decision maker into one of the three broad categories: low, moderate, high based on the risk of natural disaster (see Fig. 5). As before, the number of these categories was a parameter agreed upon by the group. In the second and third rounds, this process was repeated, this time assigning alternatives to intermediate categories (based on political stability) and narrow categories (based on manageability of the local work force). As in phase A, decision makers were free to change their preferences until each was comfortable with the ranking of his/her alternatives, and if more than one alternative were assigned to a narrow category, pairwise comparisons were used to rank the alternatives. Figure 6 displays the assignments of the candidate sites to the narrow categories and the rankings within each narrow category.

As in phase A, the score of each alternative was determined by assigning a numeric range to each broad alternative based on the risk of natural disasters: (High [0–40], Moderate [40–70], and low [70–100]). Next, these broad brackets were divided into three intermediate ones based on political stability, and the intermediate brackets are divided into narrow brackets based on the manageability of the local work force. Note that this results in $l_i = \backsim 3.33$. With $\tau = 1$, no bracket includes more than $\left\| {}^{l_i}/_{\tau} \right\| \left(\left\| {}^{3.33}/_{1} \right\| = 3 \right)$ alternatives. With these figures, the numeric range that corresponds to the narrow category that represents the bracket with *high* risk of natural disasters (RND), *low* political stability (PS), and a *low* manageability

[2] The size of each bracket as well as τ are parameters typically determined by the group.

[3] Although the decision criteria are fairly standard, there are a range of alternatives an organization can consider for locating their IT back-up facilities. Because this is a hypothetical business case, we do not specify actual geographic locations for the alternatives. Yet, the process is generic enough to work with *any* set of alternatives.

Alternative	MIR	MACL	MHRE	Aggregate	Group Ranking
MLWF	75	40	57.5	57.5	3
RND	50	67.5	85	67.5	1
PS	62.5	50	75	62.5	2

Fig. 4 Resulting scores and group ranking of the decision criteria

of the local work force (MLWF) would be [0, 3.33]. The rest of the numeric ranges for the narrow categories were determined similarly. The resulting optimization model for these rankings is as follows:

$$\text{Min} \sum_{h\in\{Alt1,Alt2,Alt3,Alt4\}} \sum_{m\in\{MIR,MACL,MEHR\}} \left|x_h^{GM} - x_h^m\right|$$

st

$$66.6 <= x_{Alt1}^{MIR} <= 70, 73.3 <= x_{Alt2}^{MIR} <= 76.6, 76.7 <= x_{Alt3}^{MIR} <= 80,$$
$$83.3 <= x_{Alt4}^{MIR} <= 86.6,$$
$$60 <= x_{Alt1}^{MACL} <= 63.3, 90 <= x_{Alt2}^{MACL} <= 93.3,$$
$$46.6 <= x_{Alt3}^{MACL} <= 50,$$
$$90 <= x_{Alt4}^{MACL} <= 93.3,$$
$$56.6 <= x_{Alt1}^{MHRE} <= 60, 56.6 <= x_{Alt2}^{MHRE} <= 60,$$
$$86.6 <= x_{Alt3}^{MHRE} <= 90,$$
$$76.6 <= x_{Alt4}^{MHRE} <= 80,$$
$$x_{Alt2}^{MACL} - x_{Alt4}^{MACL} >= 1, x_{Alt1}^{MHRE} - x_{Alt2}^{MHRE} >= 1$$

The solution is displayed in Fig. 7.

The decision team decided that the rankings are unlikely to be sensitive to slight changes in the preferences since three of the alternatives seem to clearly outrank the fourth one (Alt1). In the light of these results, the team recommends to the top management that Alt2, Alt3, and Alt4 are the three locations where the bank should invest in the facilities (Step 5.2 of the process in Fig. 1). Note that the role of the team is to make a recommendation to the top management whereas the authority to make the final decision (step 6 of the process in Fig. 1) still lies with the top management.

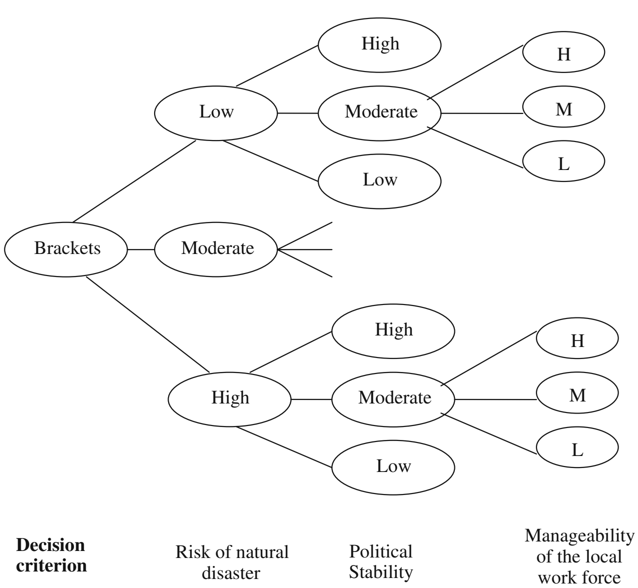

Fig. 5 Tree diagram for the categorization of alternatives

(i , j, k)	MIR	MACL	MHRE
(3,3,3)			
(3,3,2)			
(3,3,1)		Alt2>>Alt4	
(3,2,3)			Alt3
(3,2,2)	Alt4		
(3,2,1)			
(3,1,3)	Alt3		Alt4
(3,1,2)	Alt2		
(3,1,1)			
(2,3,3)	Alt1		
(2,3,2)			
(2,3,1)		Alt1	
(2,2,3)			Alt1>>Alt2
(2,2,2)			
(2,2,1)			
(2,1,3)		Alt3	
(2,1,2)			
(2,1,1)			
(1,*,*)			

Fig. 6 Rankings of location alternatives by each decision maker

5 Discussion

Business Continuity Planning (BCP) is a major strategic activity in the modern organization. The continuous operation of the IT infrastructure and information systems is a crucial component of any BCP effort. This paper addressed the important problem of redundant IT facility location decisions. Although location decisions are a well-studied research area in operations research, the decision support for locating redundant IT facilities is surprisingly weak. Our approach to the problem involves the identification of criteria relevant to this specific location problem and the introduction of a simple decision process that should be a realistic depiction of the way decisions are made in practice. Beside investment and operating costs, the criteria relevant for this problem are identified as the existing (network, power, labor, etc.) infrastructure in a country, risk of natural disasters, political stability, and the manageability of the work force. The decision process facilitates the use of these criteria, most of which are

Alternative	MIR	MACL	MHRE	Aggregate	Group Ranking
Alt1	66.7	63.3	60	63.3	4
Alt2	75	91	59	75	2
Alt3	76.7	50	86.7	71.13	3
Alt4	85	90	80	85	1

Fig. 7 Resulting scores and group ranking of location alternatives

subjective in nature, and involves the use of mathematical modeling for the gradual elimination of undesirable alternatives. This process was illustrated in a hypothetical and yet realistic case study where total cost functions (Canbolat et al. 2007) and a slightly modified version of the qualitative discrimination process (Bryson et al. 1994) were used as the mathematical techniques for generating the solution.

As with all research, there are certain limitations to what is reported in this paper. A major strength of the QDP approach is that it offers a fairly straightforward qualitative method of analysis that is easy for decision makers to adopt and use. However; the quantitative nature of model building and the following solution method make the process open to manipulation by more quantitatively-oriented members of a decision group. Since the selection of the criteria ranks determines the likely ranking of each alternative, a quantitatively-oriented user can influence the final decision by manipulating the process in those early stages where the ranking of the criteria is determined.

Further, while another general strength of (linear) optimization models (that QDP is based on) is the ability to perform post-hoc sensitivity analysis, the lack of software tools to automatically implement QDP limits the interpretability of the optimization results. In our context, such a software tool could give decision makers the opportunity to see the effect of the variations in their input on the overall decision outcome. In the absence of an automated tool, the analysis of "what-if" questions is difficult to conduct, and the full range of implications is difficult to identify and interpret.

A natural extension of this research work would then be the design and implementation of a software interface that elicits decision maker input and automatically formulates the corresponding mathematical model to be solved by a standard solver. Such a tool would also display the results of the process in a way that is easy to understand and interpret. The popularity of the AHP technique can partially be attributed to the existence of such tools for AHP. The development of such an interface for QDP should greatly improve its acceptance as a group decision support tool. The decision criteria, the process, and the techniques involved in the approach presented are intuitive and strong enough to have practical value in the design phase of BCP.

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