THE ANALYTICAL HIERARCHY PROCESS AS A TECHNIQUE FOR RETAIL STORE LOCATION SELECTION

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Store location is perhaps the most important factor affecting the ultimate success of a retail business. An unfavorable site selection is a potential hindrance to consumer awareness, and additional promotional expense may be necessary to compensate. The store location decision is typically much less easily changed, once a commitment is made, than promotional or product decisions. Furthermore, competitors may aggressively respond to a store opening in an important territory, and major changes in the legal or social environment may affect the chances for success at a given location. Moreover, the store location decision is likely to be made by a number of managers, all of whom may have different perceptions of the relative attractiveness of various locations under consideration or different criteria for selecting an optimal location.

This article illustrates how a location model based upon the Analytical Hierarchy Process (AHP) can be applied to the store location decision. The article will show how an AHP store selection model can handle these complications which make location selection a difficult process. AHP is a useful technique for structuring multicriteria decisions – it identifies the preferred alternatives, based totally upon the respondent's judgment, intuition and experience. The AHP technique has certain properties which make it attractive for application to this decision: it requires only easily-obtainable, inexpensive data, and actively incorporates – in fact, is driven by – managers' subjective judgment inputs. Furthermore, the "Expert Choice" version is inexpensive to use in terms of both time and money, even when sensitivity analysis is employed.

Traditional Retail Location Models

Among the store location decisions facing the retailer is the choice of optimal site(s) from a set of identified possibilities and deciding the best store configuration (i.e., size, design, layout) ([25], p. 445). A number of classes of location selection

techniques have been proposed and discussed in the literature, including checklist methods, analog approaches, regression models, and location allocation models.

In the *checklist method*, the manager evaluates a set of factors (such as demographics, level of competition, and expenditure patterns) that are likely to have an effect on sales and costs at various sites [5]. For a discussion of problems with checklists, see Stanley and Sewall [34].

Under the *analog approach*, the manager chooses an existing store or stores which match the proposed store on important variables (store type, competition, site, etc.). Sales volume for the proposed store is estimated using the per-capita sales volume of the analog store(s). This method reportedly is popular among retail managers [1]; however it suffers from selection bias in determining the analog store.

Regression models use multiple regression to analyze the determinants of performance. Performance is expressed as some function of a collection of performance factors (i.e., distance, image, etc.). For a general statement of the functional relationship, see Haynes and Forthingham [15]. Anderson [2] provides an application of this technique, and other examples are present in the literature ([4],[7],[28]). Common problems of multiple regression models are reviewed by Craig, Ghosh, and McLafferty [5].

Location allocation models are used to evaluate simultaneously a set of facility locations, with the intent of optimizing market area sales or profits. The main objective in location allocation models is to "allocate" customers across store locations (existing and proposed), to predict resulting sales and profits.

The Huff model ([18],[19],[20]) is a simple location allocation model, based on a gravity model, that determines probability of shopping at a given store as a function of size and distance. Related models and discussions appear in ([3],[9],[10],[16], [21],[22],[34],[35]). Another simple location allocation model, MULTILOC ([1],[38]), is a multiple store extension of the basic Huff approach. More complex location allocation models include the multiplicative competitive interaction (MCI) model of Nakanishi and Cooper [27], which incorporates many store attributes in addition to size in projecting sales volume, such as store image, location, and credit availability (see [23]). For sample applications, see ([14],[16],[17]).

Certain other location allocation models have also been developed ([8],[10],[11],[12], [13],[26]). Many of these are generalizations of the MCI or MULTILOC models suitable for application in specific complex environment. For example, the game-theoretic approach of Ghosh and Craig [10] is appropriate when the retail environment is unstable. In the application of the more complex models, data requirements, cost, and complexity of use are comparatively high. For a good review of the literature on location models, see Craig, Ghosh, and McLafferty [5].

Limitations of Traditional Models and Potential Contributions of AHP

There are some drawbacks associated with the use of the currently available store location models. The simpler models are easy to understand and apply, and use readily available data. However, much useful data are ignored, such as store attributes,

environmental characteristics, competitive retaliation, and so on. These models also provide no guidelines for extension to more difficult problems. On the other hand, the more complex location allocation models are capable of handling very complex problems but data collection requirements and resulting costs may be prohibitive. Additionally, managers may not be receptive to a highly complex model (which they may not fully understand) making location decisions for them as they may not feel involved in the decision-making process. None of the current versions of the complex models described above incorporates the subjective inputs of multiple decision makers. Ideally, the decision process should combine judgment based on objective analysis of relevant data (sales, costs, etc.) with subjective inputs from expert managers.

A location decision model based on the Analytical Hierarchy Process (AHP) overcomes several significant drawbacks of both simple and complex methods. It has relatively low data requirements and is relatively simple and inexpensive to apply. Nonetheless, AHP is capable of handling situations with many factors that can have an impact upon sales or profits, such as environmental uncertainties, nature of the competition, new store types, etc. It also provides the advantage of permitting several managers to provide subjective inputs. In fact, an appealing feature of AHP is that the decision maker is actively involved in the decision process – his or her managerial expertise, experience, and intuition are reflected in judgments which drive the model.

Making the Location Decision With AHP

The AHP approach to modeling allows one to structure complex, multiperson, and multicriteria decisions using a practical method directly accessible by managers. Numerous applications have been developed in such diverse areas as economic planning, energy policy, health, conflict resolution, materials purchasing, portfolio selection, accounting, sociology and architecture ([6],[33],[36]). A recent review by Zadehi [37 listed well over 200 published applications.

According to Johnson [24], the AHP involves four basic steps:

Step 1: Set up the decision hierarchy by breaking down the decision problem based on managerial purposes (top levels) through relevant intermediate levels, down to the level where the problem can be operationally solved. This results in the construction of a tree-like hierarchical model, such as appears in Figure 1.

Step 2: Collect input data in the form of pairwise contributions of each element with regard to the objective of criterion on the next higher level. ("Pairwise" means that the elements are taken two at a time, and the extent of one's impact *relative* to the other is assessed.)

Step 3: Solve the eigenvalue problem of the matrix specified in Step 2 to estimate the relative weights of the decisions elements (for each matrix).

Step 4: Aggregate the relative weights of decision elements by hierarchical composition to obtain composite priorities of the elements at each level. Simply put, given the hierarchical model of Step 1 and the input data of Step 2, the weights

of each branch of the hierarchical tree are calculated (Step 3), and the available choices are ranked in order of how well each would achieve the manager's stated objectives (Step 4).

Figure 1
Complete Hierarchy: Store Location Decision
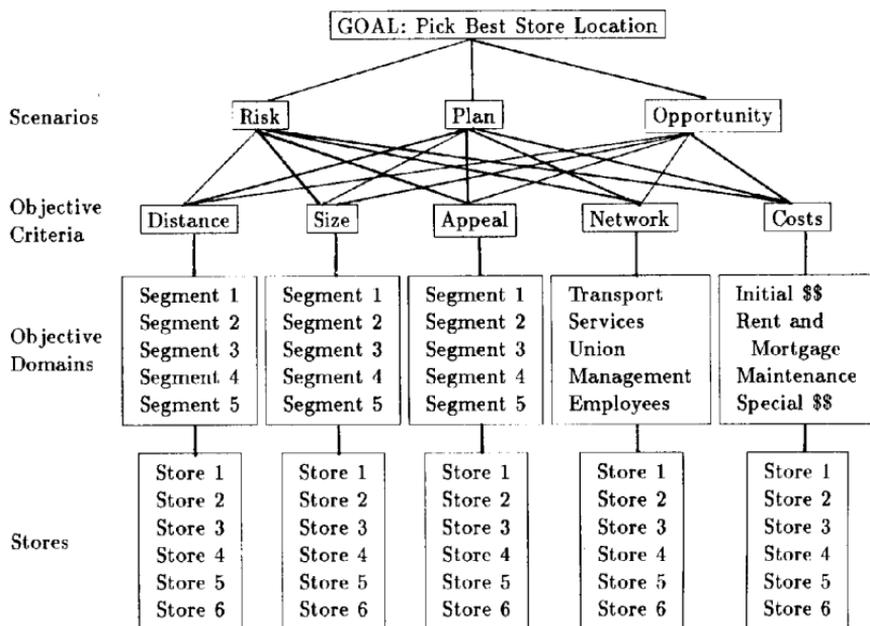
LEGEND:

Goal: Pick the best store location.

Scenarios:

        Plan – Most likely scenario.

        Risk – Worst case scenario.

        Opportunity – Best case scenario.

Objective Criteria:

        Distance – Distance preference of each segment for each store.

        Size – Width of product line preference of each segment for each store.

        Appeal – Attractiveness preferences of each segment for each store.

        Network – Importance of each providing function for each store.
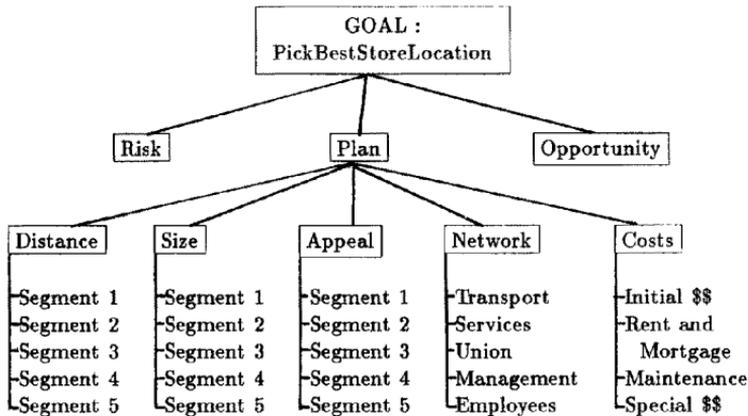
        Costs – Cost category importance impact for each store.

Note: For additional explanation, please refer to the Appendix.

"Expert Choice" software (Decision Support Software Inc.) is a commercially available AHP package. Although the problem complexity it can handle is slightly constrained, it is mathematically consistent with the "true" AHP procedure. Given

Figure 2
Detail of Hierarchy for Plan Scenario: Store Location Decision

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                          ┌─────────────────────┐
                          │      GOAL :          │
                          │ PickBestStoreLocation│
                          └─────────────────────┘
           ┌─────┐            ┌──────┐           ┌─────────────┐
           │Risk │            │ Plan │           │ Opportunity │
           └─────┘            └──────┘           └─────────────┘

┌──────────┐  ┌──────┐   ┌────────┐   ┌─────────┐   ┌───────┐
│ Distance │  │ Size │   │ Appeal │   │ Network │   │ Costs │
└──────────┘  └──────┘   └────────┘   └─────────┘   └───────┘

├Segment 1   ├Segment 1  ├Segment 1  ├Transport   ├Initial $$
├Segment 2   ├Segment 2  ├Segment 2  ├Services    ├Rent and
├Segment 3   ├Segment 3  ├Segment 3  ├Union       │  Mortgage
├Segment 4   ├Segment 4  ├Segment 4  ├Management  ├Maintenance
└Segment 5   └Segment 5  └Segment 5  └Employees   └Special $$
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the hierarchical model and input data, it performs the mathematical computations to produce the weights and priorities of Steps 3 and 4. The availability of this software makes AHP accessible to a larger number of potential users.

Sample Application of AHP to Retail Location

We illustrate the application of AHP to store location using the example of a fast-growing, but small, Midwest grocery chain (prior obligations require anonymity of the chain). The chain must open one new store (to be chosen from a set of six possibilities) in one geographic sector of Kentucky during the next planning period. Although some details of the problem are simplified for illustrative purposes, several real world externalities have been included for consideration, such as management's concern for employees, management and union preferences, and likelihoods of resistance. Also, various multiple objective or two-level concerns such as profitability and size (square footage) which may be highly correlated over locations – possibly nonlinearly – are considered. Let us examine the AHP-aided decision process step by step.

Step 1.

The AHP was used to guide the selection of the best store from the six potential sites. A hierarchy was developed jointly by the researcher and the vice-president for retail operations and is shown as Figure 1. Some detail is lost in this figure due to the complexity of the problem, so an expanded view containing only the Plan scenario is shown in Figure 2.

Figure 3
Results of Pairwise Comparisons: Likelihood of Scenarios

	Risk	Plan	Opportunity
Risk	1	1/5	1
Plan	5	1	5
Opportunity	1	1/5	1

Figure 1 indicates that, given the overall goal of picking the best store, one must consider several levels of criteria. At the highest level is the realization that the environmental situation (competitive reaction, economic conditions, consumer reactions, etc.) may occur as foreseen by management ("Plan"), may be worse than foreseen, leading to lower profits ("Risk"), or may be better than foreseen ("Opportunity").

At the next level, five objective criteria (selected by the manager as being the most important criteria in store selection) are detailed. Under each of these criteria is a set of objective domains specific to each store's ultimate profitability. The criteria selected by the manager were Distance, Size, Appeal, Network and Costs, whose operational definitions for this study appear in the Appendix.

Under the objective criteria are the objective domains (see Figures 1 and 2). For Network and Costs criteria, the relevant objective domains are as listed in the Figure. For the Distance, Size and Appeal criteria, sales potential of each market segment was selected as the appropriate objective domain. Since the projection of potential sales at each store location requires the evaluation of distance, store size, and appeal on a segment-by-segment basis, one must also adjust for some segments having greater sales potential than others, due to size or buying power. A useful way to incorporate sales potential into the model is to get the responding managers to assess subjectively the sales potential of each identified segment on a numerical scale, and to use these values to "weight" each segment's impact on sales in the model. Thus, for each considered store location, the manager separately assesses both potential sales and the associated cost tradeoffs, as well as other relevant factors.

Under each of the objective domains are the "leaves" of the analysis (in this case, the six store locations). In order to pick the best store using this method, each of the six stores must be evaluated under the relevant criterion for each scenario.

Step 2.

The objective is for management to evaluate each level of the hierarchy by means of paired comparison rankings. The dominance scaling approach employing a scale of 1 to 9 suggested by Saaty [33] is used. Experience with the nine-point scale has shown that it provides a reasonable representation of the magnitude of the relationships between the items (see discussion in the Expert Choice manual, pp. 5-2 to 5-5.)

Begin at the top of Figure 1. The manager, when prompted by either the researcher's questions or the Expert Choice program, may say that the Plan scenario is five times more likely to occur than either the Risk or Opportunity scenarios, which are equally likely. This input would result in the pairwise comparison table as shown in Figure 3. The first row can be interpreted as: "Risk is as likely to occur as Risk; Risk is one-fifth as likely to occur as Plan; Risk is as likely to occur as Opportunity." The elements of the lower triangle are the reciprocal of the upper triangle; thus, only the data for the upper triangle of the matrix must be collected. The procedure was carried down to the next level, and so on. For example, at the next lower level, the relative importances of distance, size, appeal, network and costs in the location decision were pairwise compared by management. Inputs were obtained in this manner for the entire process.

Step 3.

In Step 3, each input matrix is analyzed using the eigenvalue method to produce relative weights for each alternative under each objective. The argument for this solution technique is based axiomatically on Saaty [33] and is discussed in ([29],[30],[31], [32],[33]). Briefly stated, if the evaluator could know the relative weights at each level, he or she would be perfectly consistent across the comparisons of Step 2. Since this is generally impossible due to problem size, the weights are evaluated for consistency using a consistency index based on the eigenvalues (weights) derived from the input matrices. By general agreement, 10% is taken as the baseline maximum inconsistency level in large problems, and 6% or less in small problems. Incidentally, in a real decision-making situation, it is possible that inconsistencies may arise – for example, the respondent may actually prefer X to Y, Y to Z, and Z to X. AHP will "flag" this seemingly inconsistent set of inputs by reporting a high inconsistency level. But, if the respondent confirms that these inputs accurately represent his or her subjective judgments, the AHP model uses them. In short, it can handle seeming inconsistencies in managerial judgment.

The final synthesized weights for the objective criteria under the three scenarios were calculated by Expert Choice (see Figure 4a).

Since these are global weights (that is, after synthesis), the Plan objectives are weighted higher than those for Risk or Opportunity. However, it is easy to see that management has substantially different views of the importance of the objective criteria, depending on which scenario they are considering. Simply comparing the within-scenario rank order of the objectives will reveal this tendency.

Compare the relative importance of the objective criteria under the risky scenario (column 1) in Figure 4a to the importance obtained under the opportunity scenario (column 3). In the risky case, management would place greatest importance upon minimizing costs (global weight of 0.051 for Cost is the highest). The Network functions (0.024) are also important here. The only other criterion of importance is Size (0.039), which refers to the width of product line available in the store. By contrast, under the opportunity scenario, importance shifts **away** from Costs and Network and

toward the criteria of Size, Distance and Appeal. Management would take advantage of the greater opportunities in this optimistic scenario by opening a bigger store, closer to the major market segments, and by providing services and features (such as an in-store bake shop, photo lab, etc.) to increase attractiveness (appeal). The relative importances of the five objective criteria are more closely comparable under the Plan scenario (all are within the range 0.114 to 0.139).

Figure 4
Results of the AHP Application

a) Final Synthesized Weights of Criteria Under Each Scenario

b) Synthesis of Leaf Nodes with Respect to Goal
   (Overall Store Location Ranking)

Step 4.

Step 4 aggregates and synthesizes all the weights calculated in Step 3. These composite or global weights show the relative contribution or impact of the particular cell on the overall (global) objective of the AHP decision problem. The Expert Choice software performs all required computations and syntheses required and checks for consistency levels; also, it allows the manager or researcher to re-input inconsistent matrices.

The Expert Choice program solved for the full AHP result (not shown here in the interest of space) and presented it in the form of a synthesized tree listing, as appears in Figure 4b.

In Figure 4b, Store 2 is shown as the overall best choice, being slightly preferred to Store 1. Stores 6, 4, and 3 were closely clustered, while Store 5 was clearly the

last choice among the six. This final ranking is the overall result of the synthesis of the dominance scaling of each leaf (store) under the hierarchy of decision criteria previously presented. The overall consistency in the model is 3% which may be considered a very good score for a moderate-sized problem such as this ([33],[37]).

Practical Issues In Model Use

The authors have used AHP in this and other applications with favorable results. Despite the apparent complexity of the model, most respondents are enthusiastic and curious about the technique, and express little difficulty in completing the paired comparison task.

At any point in model construction or paired comparison elicitation, the researcher can stop, get the model up on the screen, and ask the manager if he or she is "comfortable" with the criteria and weights included so far. If not, these can be adjusted. As a final check, once the model is run, a visual representation of the rankings (Figure 4b) is shown to the respondent, who then is asked whether the ordering as calculated by AHP is an accurate representation of his or her own subjective orderings. Thus, the respondent has an opportunity to review his or her input to the model, and the researcher can revise the entries according to the comments of the respondent. In the authors' experience, almost all respondents confirm that the model had indeed captured his or her understanding of the decision problem – and in some cases were surprised at the insights provided in the results. Many respondents (even those somewhat wary of personal computers) make favorable comments about the computer graphics contained in Expert Choice – this appealing feature enhances their interest in the task. The authors feel confident in the solutions provided by AHP, because of the high degree of interaction between manager and researcher.

Summary And Conclusions

The purpose of this article has been to offer the analytical hierarchical program approach as an alternative selection process to many of the techniques currently in use. The currently-available store location models all have certain limitations which have been briefly discussed. As a possible alternative, the AHP approach reduces or eliminates many of these problems.

The AHP store location model presented here is a judgment-based model suitable in situations of a highly risky and unpredictable environment, as well as in less complex environments. It is a flexible process which overcomes the weakness of simple checklists and gravity models, which ignore much useful data, while being simpler to use than the math programming methods. Although checklist methods may contain or list similar objectives to the ones included here, these approaches do not provide explicit rules for the selection of the best location, nor provide criteria such as environmental risk or instability of segment preferences. Also, the methods based on integer programming have not yet been adequately extended to allow for multiple objectives, multiple decision makers, nor subjectively weighted goals.

AHP relies heavily on managerial judgment for input, which can be either a strength or a weakness. On the one hand, it may have greater appeal among practicing managers than the math programming models, and is less likely to be criticized by management for giving unrealistic answers, since the answers will reflect managerial thought. In the illustrative example, management was concerned with satisfying union requirements and placating employees as well as meeting customer needs when choosing a retail location. On the other hand, if the manager's judgments are wrong or insufficient (for example, not all the relevant branches of the hierarchical model have been identified), this will be reflected in a poor choice model. It is up to the researcher to be thorough and persistent, and to probe for further information from management whenever possible.

AHP compares favorably to other methods for reducing subjective comparison data to interval data, such as MONANOVA (monotonic analysis of variance). Unlike MONANOVA, AHP does not require orthogonal arrays. Hence, AHP can use manager's criteria, even if they are non-orthogonal. Also, if more than one manager is included, they are not required to use the same criteria. Furthermore, they are allowed to weight criteria directly, or indirectly weight the criteria by using paired comparisons. AHP is thus superior for this type of choice problem, providing for non-orthogonal arrays, direct combination rules, and global ranking of alternatives (as opposed to part-worths from MONANOVA).

Ideally, it would be desirable to present empirical evidence indicating that the manager's store location decision was improved by the use of AHP. However, since the manager's personal preference prior to the application of AHP was not provided, this was not possible. One could therefore still ask if AHP is capable of improving the manager's (unaided) decision – or, to put it another way, whether the solution to the eigenvalue problem is the solution to the managerial problem. The goal of applying the AHP model is perhaps not to make "better" decisions, but more correctly to make "more rational" decisions. Many managerial decisions (such as store location selection), as well as personal choices (choosing a home or career), are extremely complex and require the consideration of several factors and their relative effects and importance all at the same time. The AHP model, as made available in the Expert Choice software, is not designed to "tell (the respondent) how to think, but it does make (his or her) own thoughts clearer, easier to organize, and more presentable to others .... (The program) does what the unaided mind has difficulty doing. It treats a decision as a whole system and not as isolated parts" (From the Expert Choice manual, p. 2- 2). The decision maker may have little difficulty setting up the hierarchical structure, once he or she sets out to do so; and indeed may easily be able to make all the individual paired comparisons. However, in a complex decision, it is almost impossible to take into account all of these factors appropriately. It is easier for the respondent to make his or her decision based on only one or two important criteria (i.e., looking at only maximizing sales when choosing store location), while not placing enough importance on other criteria (transportation costs, likely union problems, etc.). AHP simply makes the decision process more rational by taking as

datum all of the manager's judgments and combining them in a way that the manager might not be able to do by him or herself.

The AHP approach is not without limitations to its application to the retail location process. While this technique allows for multiple objectives, multiple decision makers, and subjectively weighted goal, it is not likely to be readily adaptable to extremely complex decision problems. The complex math programming models have an ability to achieve near optimization within "network" location problems which are not directly assessed with the AHP, thus in some instances the complex models will be preferred. When the problem is extremely large, as in Ghosh and Craig's study [12], AHP can be a useful adjunct for manager-based sensitivity analysis or phase-in (ramp-up) operational planning.

Since the use of AHP depends in part on the ability of managers to rate and rank properly the various decision elements as inputs to the model, the complexity which the model can handle at any one level is limited to the level of complexity which the manager can handle at any one level of the hierarchy (the model itself handles complexity across levels). A possible related stream of research would be to determine whether the direct management involvement in the retail location decision process improves management's commitment to the success of the decision. Since commitment frequently determines success, such a finding would offer strong support to retail location decision techniques (such as one based on AHP) which involve management's subjective inputs.

Regardless of the results of this or any further research in the retail location area, the location decision itself will continue to be one of the most important decisions the retailer faces. Thus, any research activity whose results can help to improve the quality of decisions made should be of interest to conscientious retail planners.

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Appendix
Criteria Used For AHP Application

Distance: Distance of a site from major user segments is evaluated as to the preferences of each segment. In this application, distance was evaluated in terms of physical separation between the user segments as well as the ease of traveling (i.e., whether the distance could be traversed on a highway or on slower city streets). Estimated time of travel to each store site was also considered by management.

Size: The square footage of the proposed store is evaluated. This is an important criterion as larger stores allow the store manager to stock a wider product line. For some (but not necessarily all) market segments, availability of a wide product line is an important factor in choosing a store.

Appeal: Store placement and overall aesthetics of the proposed layout (for example, the appeal of the surrounding shopping mall, if applicable) are evaluated segment by segment, recognizing that differences in preference may exist across segments.

Network: An evaluation of store fit into the current network is carried out over the domains of transportation (time and costs), services availability, possible union problems, management preferences and attractiveness for employees. The degree to which each of these factors is likely to be a problem at each location is estimated by the manager.

Costs: The major costs which must be incurred to do business at a location are estimated by the manager. These include initial dollars invested, rent or mortgage expenses, maintenance costs, and any special costs peculiar to a location.

Two of the criteria (Network and Costs) may be classed as *operations* criteria, while the others (Distance, Size, and Appeal) are *marketing* criteria.

The domains under the operations criteria are different from those under the market criteria. Under Network, one finds several resources providing functions: management considers the availability of each of these in the location decision. Under Costs appear several categories of costs which must be considered. By comparison, under the market criteria, the views of each of five market segments are appropriately placed. Note also that the relative importances of the criteria may differ for different scenarios; hence, one must repeat the analysis three times, once for each of the possible scenarios.