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For a retail store planning expansion, site selection is critical. A poorly-sited location represents lost capital, a drain on profits, and potential harm to the company's reputation. Moreover, for the past several decades, the range of choices available to a retailer has continued to expand, stretching the retailer's resources available for site selection. According to the U.S. Census Bureau (2010), between 1986 and 2009 (the

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most recent data published), the number of shopping centers increased every year across all sizes of shopping centers, despite potentially adverse changes in the economy, demographics, and competition during the period. As in most complex decisions, site selection involves tradeoffs that reflect the decision maker's preferences. Advances in decision analytics aid the solution of such complex problems. This article describes the development of a multiple-attribute analytic model used by a chain of retail stores to assist in the selection of new store locations.

The theory underlying multiple-attribute decision models was developed in the 1960s, 1970s and 1980s, as summarized in Keeney and Raiffa (1976), Zeleny (1982), Dyer (1992), and Zanjirani et al. (2010) with numerous immediate applications, such as Keeney (1973b). Multi-attribute models are particularly applicable in decision situations in which no single "natural" objective,

such as profit maximization, exists. Stimson (1969), for example, developed a multi-attribute model for decision making in a public health facility. Zanjirani et al. (2010) specifically looked at multi-attribute location models.

The models are also applicable in cases with a natural objective, but the alternatives being evaluated cannot be expressed in terms of that objective in any practical manner. The scoring model by Lucas and Moore (1976) is an example of such an application. Dyer et al. (1992) noted that scoring models received much attention in Eastern Bloc countries because of their suitability to central planning. Their applicability to large government projects led pioneers in the field such as Keeney and von Winterfeldt to studies such as the disposal of nuclear waste (1994). Huber (1974a, 1974b) and Dreyer (1974) reviewed early studies in these areas.

Saaty, in a series of books and articles from 1980 to the present (e.g., 1980, 2008), developed and refined the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) methodologies for analyzing multi-attribute problems. Unlike most multiple-criteria decision models, which assume a single decision maker, AHP also works well in group decision making. The citations for applications of AHP and ANP from 1980 to the present are too numerous to mention. A good source is the *Proceedings* of the biannual meeting of International Symposium on the Analytic Hierarchy Process.

Another application, the one considered in this article, involves the case in which a single natural objective exists, but other considerations such as the attitude of the decision maker, the nature of the decision process, or higher goals preclude its use as a decision variable in the evaluation of a particular project. To a retailer, site selection is critical and complex and is an important part of the firm's overall strategic policy. Because alternative sites may each excel on different dimensions, multi-attribute decision modeling provides a means of assessing and quantifying the decision maker's preferences.

In this study, the attitude of the decision maker (DM) was important because implicitly he already had a set of attributes upon which he

based his decisions (i.e., his intuition or "gut feeling"). Furthermore, the nature of the decision process often demanded that he make quick decisions based upon the immediate available information. For an excellent review of the relationship between intuition and analytical decision making, see Dane and Pratt (2007). Because of the nature of the problem (including a single DM), the need for rapid, uncomplicated decision making and the need to reflect the intuition of the DM, the researchers chose to construct a scoring model based upon multi-attribute utility theory to assist the DM in locating his new stores.

This study is divided into three sections—the problem and the general approach to its solution; a detailed description of the elements of the model; and the formulation, construction, and evaluation of the model.

The Problem

The subject firm is a national chain of retail stores, owned and operated by the parent company, and ranks highly in most common measures for its industry. The company had been experiencing a period of rapid growth in number of stores, and expected this growth to continue for several years.

Recently, the company decided to open additional stores only in regional shopping malls. Regional malls are enclosed shopping malls

with at least two anchor stores and serving an area of at least 100 square miles. The problem became to decide which malls provided suitable locations for its stores.

Brockman, Benton. and Turley (2001) describe a typical managerial approach to mall-related site selection. The standard approach to the problem would be to identify all of the available alternatives in a specific geographic area over a period of time, obtain background information on each, investigate the potential of each mall, visit and tour each "to get a 'feel' for its viability" (to assist in developing a sales forecast for that site), rank them according to their desirability (utility), verify leasing availability, and choose all that are acceptable given some budgetary constraint. Models of this type are described in Gautschi (1981) and Smith (2003). Plastria (2001) provides an overview of location optimization models.

This firm's location decisions, however, were made one at a time without regard to such a budgetary constraint and with a minimum of comparison of alternatives. The budgetary constraint had been ignored because of the apparent strength of the company's financial position. The company was privately owned, used no long-term debt financing to date, and had arranged access to a multi-million dollar line of credit. The DM literally could not

decide to open stores and actually open them fast enough to exceed any budgetary constraint. Decisions were made on each mall separately with minimum comparison since prospective locations became available at unpredictable times throughout the year. Furthermore, some locations would place time constraints upon the decision. The dates by which a decision had to be made were also irregularly distributed across the year.

Although certain malls could be rejected out of hand as unsatisfactory and others could be immediately accepted, there would be a large number of sites which could be rated anywhere from "probably acceptable" to "probably unacceptable" each year. The problem was to characterize these questionable malls and to arrive at a measure for the utility of each location.

Mathematical decision models can be unwieldy to the user either by being an obscure black box the DM does not understand (such as most of the models described in Zanjirani et al. (2010)), or by requiring extensive, complicated inputs (see Nwogugu, 2006). To gain acceptance of the model by management, the firm's current system was the basis of the model. The objective of the model was to obtain a method of making the decision criteria explicit and the decisions consistent and replicable.

The general approach was first to determine the relevant attributes used to characterize the malls. This was accomplished through interviews with the DM, the director of development. After several interviews, 14 attributes and weights reflecting their relative importance were determined. A scale to provide a range over which the attributes could vary was then devised. The decision process consisted of the DM assessing prior probability distributions on the attributes for a given mall and updating the priors if more information became available before making the decision. At the decision point, an index representing the expected utility of the mall was calculated. The decision was made based upon the value of the index.

Prior to the development of this model, the DM believed that he personally had to see the location and form his "gut feeling." As mentioned earlier, a tour of a potential site is standard procedure in mall site selection decisions. Continued and widespread reliance in the industry on past experiences, or "gut feeling," is documented by Clarke et al. (2003) among others as being a response to the limitations and complexities of quantitative site selection models and by Wood and Browne (2007) among others as having the most value when used in conjunction with such quantitative techniques.

In the present case, the cost in time and dollars of having the director of development personally conduct each visit had not been considered. A valuable by-product of the model is this cost reduction. Since the utility function of the DM is imbedded in the weighting scheme, he could train and send others to potential sites to make the basic evaluations and still have the decision reflect his preferences.

An additive utility function for aggregating the expected utilities of the individual attributes was selected for the model. Fishburn (1969; 1967), Keeney (1973a) and others show that an additive function implies that the attributes are independent. For the present analysis, tests revealed that the attributes could be treated as independent. The decision maker had no difficulty in considering the attributes individually. Richard (1975) demonstrated that an additive utility function implies pair-wise multi-attribute risk neutrality. It is not clear how to test the assumption of risk-neutrality in a multi-attribute problem. The alternate is the use of an interactive aggregating function, as in Keeney (1973b). This approach was rejected because of the nature of the decision process. The use of interactive functions requires a large investment of time and effort by the DM. With the DM required to make decisions many times per year, ease in

using the model became an important objective.

The Model

In a decision analysis framework, the decision about a mall is the set of acts. There are only two acts—to put a store in a mall or not. The states of nature or outcomes are the n-tuples of realizations for the 14 attributes, each n-tuple yielding a consequence in terms of "utility" or the index. The 14 attributes are identified in Table 1. Although there are no experiments as in a standard decision analysis, the DM can obtain additional information on the attributes through his contacts in the industry. The cost would usually be obligating him to return the favor in the future.

The 14 attributes represent two separate dimensions of the site evaluation—characteristics of the shopping mall (attributes 1, 2, 3, 4, 5, 6, 8 and 11) and characteristics of the trade area (7, 9, 10, 12, 13 and 14). These or similar attributes commonly appear in location research, as surveyed in Mejia and Benjamin (2002), Pan and Zinkham (2006) and Zanjirani et al. (2010).

The weights for the attributes were determined by the classic Churchman-Ackoff (1954) procedure to rank the attributes. The procedure was conducted with the DM so they would incorporate his assessment of their importance. A weight of 20 was assigned to the top ranked attribute. The DM assigned values equal to or less than 20 to the rest. Twenty was chosen to yield a sufficient degree of distinction among the attributes. Ultimately, the weights for five of the attributes depended upon the assessed scores for that factor. Each of these five were separated into two variables and combined with a (0, 1) delta function. Analytically, the model therefore contains 19 attributes, but evaluates a subset of only 14 of them (see Fishburn, 1968). The attributes and their weights are given in Table 2.

For any given mall being evaluated by the DM, each attribute was allowed to assume values on a six-point scale: (-5, -3, -1, 1, 3, 5). For each attribute identified as being deterministic (discussed below), the DM is required to assign one of these values as its score. For each stochastic attribute, the DM assigns a probability to each of the six points on the scale. The expected score for each of these attributes is weighted and summed together with the weighted scores of the deterministic attributes to yield a total expected index of the utility of the alternative. The DM can make the decision at this point, or gather additional information, reassess his priors, and recalculate the expected utility.

The model can be expressed as follows:

Let S be the set of all possible outcomes, and $S = S_1 \times S2 \times \ldots \times S_{19}$, where $S_1, \ldots, S_{19}$ represent the attributes. If s_{ki} = the score for attribute i in the kth outcome, such that $s_k = (s_{k1}, s_{k2}, \ldots, s_{k19})$ for $k = 1, 2, \ldots, n = 6^{19}$; and $p(s_{ki})$ = prior probability of s_{ki}; then the index

$$I_k = \sum_{i=1}^{19} s_{ki} w_i \delta_i \text{ is the}$$

consequence of the kth outcome, where

w = the weight for attribute i which reflects the decision maker's utility function, and

δ = the (0, 1) delta function.

Furthermore, let

a_1 be the decision (action) to put a store in a mall, and

a_2 be the decision not to put a store in a mall.

For either of the two decisions, any one of the k outcomes is possible. The consequence associated with each outcome following a_2, the decision not to put a store in a mall, is assumed to be zero. Although one could argue that choosing a_2 will result in costs avoided or profits foregone, the company officers in this case perceived the consequences as zero since they had no way of determining how a rejected location would have done. The

Table 1
Attributes

1. Leasable Square Footage: The total for the mall.

2. Anchors: The major tenants. Most malls have two or more large department stores (often located at opposite ends of the mall). This attribute reflects the relative drawing power of the anchors.

3. Type of Mall: Malls can generally be characterized on a continuum ranging from a discount mall to a fashion mall.

4. Mall Sales Per Square Foot: Actual if the mall exists, forecasted if it is a new mall.

5. Store Location in Mall: The stores depend a lot on walk-in traffic. Proximity to traffic flows is important.

6. Attitude of Merchants in Mall: The attitude toward the mall itself.

7. Prospects for Clustering Stores: Geographically clustered stores in the chain are easier to manage than widely separated stores.

8. Importance of Developer: A political factor, There are several large developers who build malls nationally. Leasing space in one mall can lead to being offered more desirable opportunities later.

9. Trade Population: Population of the trade area serviced by the mall.

10. Other Malls in Area: The level of competition among malls in this area.

11. Competition in Mall: The degree to which other stores will be offering the same products in the mall.

12. Area Competition Outside Mall: The degree to which other stores outside the mall sell the same products.

13. Average Income in Trade Area

14. Defense Motive: The desirability of a location to preserve the existing share of a market. This was of particular importance in the region of the home office.

Table 2
Attributes and Weights

Attribute	Weight	
1. Leasable Square Footage	20	
2. Anchors	20	
3. Type of Mall	20	
4. Mall Sales per Square Foot	1	if score > -2
	15	if score ≤ -2
5. Store Location in Mall	1	if score > -2
	20	if score ≤ -2
6. Attitude of Merchants in mall	6	
7. Prospects for Clustering Stores	17	if #9 score ≥ 0
	10	if #9 score < 0
8. Importance of Developer	20	if score ≥ 0
	1	if score < 0
9. Trade Population	12	
10. Other Malls in Area	20	if score ≤ 0
	12	if score > 0
11. Competition in Mall	20	
12. Area Competition in Trade Area	10	
13. Average Income in Trade Area	10	
14. Defense Motive	10	

consequence associated with each of the k outcomes following a_1 is:

$$I_k = \sum_{i=1}^{19} s_{ki} w_i \delta_i \text{ , and}$$
$$a_1 = \sum_{k=1}^{n} \{I_k \prod_{i=1}^{19} [p(s_{ki})]\} =$$
expected utility from a_1.　(1)

The objective function becomes:

max (a_1,0)

An additive utility procedure as described in the first part of the article implies that:

$$a_1 = \sum_{i=1}^{19} [\sum_{j=1}^{6} s_{ji} p(s_{ji})] w_i \delta_i \text{ (2)}$$

The two expressions for a_1 are identical, however. Using the expected value operator, the original expression (1) becomes:

$$a_1 = \sum_{k=1}^{n} \{I_k \prod_{i=1}^{19} [p(s_{ki})]\} = E(I_k)$$

And the second expression (2) becomes:

$$a_1 = \sum_{i=1}^{19} [\sum_{j=1}^{6} s_{ji} p(s_{ji})] w_i \delta_i =$$
$$\sum_{i=1}^{19} (E_i(s_i w_i \delta_i)) = E_i \left(\sum_{i=1}^{19} s_{ki} w_i \delta_i\right) = E(I_k)$$

The **decision rule** is to take the location (choose a_1) if a_1 is greater than zero and to reject if a_1 is less than zero. If $a_1 = 0$, the DM must decide if he is truly indifferent, or if, by reviewing his priors and scores, a decision can be made. Although the researchers have included an objective function as part of the model, from the DM's point of view, it is certainly implicit. And, as Dyer (1992) points out, "...the user need not be aware that there is a value function."

Developing and Evaluating the Model

The development of the model involved a formulation phase, a deterministic phase, a stochastic phase, and a testing and revision phase. In the formulation phase the relevant attributes and weights were determined. The deterministic phase involved checking the sensitivity of the attributes. The independence of the attributes was tested in the stochastic phase. Adjustments to and validation of the model comprised the final stage.

The decision maker perceived his present decision process as a two-stage process consisting of first getting a subjective feeling about the location and then making the decision. He resisted efforts to identify objective factors that entered the decision. It became necessary to conduct several non-directed interviews in which he just talked about making a

decision. It was possible to extract the 14 attributes from notes taken at these interviews. Although initially reluctant to participate in the construction of the model, when presented with the list of attributes he became fully cooperative.

The second step in the formulation was to determine the weights or marginal utilities associated with each attribute. The decision maker was required to rank the attributes in order of importance. The DM initially resisted this, however, saying that the realization of the attribute values influenced the rankings for some of the attributes, specifically those numbered 4, 5, 7, 8 and 10. Therefore, each of these attributes was treated as two separate attributes, as described in Part II.

The scoring scale for the attributes (-5, -3, -1, 1, 3, 5), described earlier, was devised to

(1) Satisfy the intuitive feelings of the DM, namely, a low rating deducts from the overall score;

(2) Maintain a constant interval between scores and avoid the use of decimals; and

(3) Present the DM an even number of choices thereby avoiding any tendency to give "average" scores.

The DM was forced to give a mall either a positive or negative score on each attribute. A decision worksheet (Table 3) was developed listing the name and providing a scale for each attribute. The worksheet format allowed the DM quickly to rate and re-rate a mall as he moved toward making a decision. It also provided for the recording of a "decision trail" to facilitate future revisions and adjustments in the model. The DM had trouble at first with the concept of stochastic attributes. After a brief training session and a little practice, he was able to assign probabilities with little difficulty.

In order to test the sensitivity of the attributes in the deterministic phase, it became necessary to determine "most likely" values for the attributes. To acquire these, and give the DM practice in operating the model, the DM was asked to score each of his existing stores as if he were making the original decision on them. Unexpectedly, the DM also included several locations he claimed he never would have accepted, but which were opened before he assumed his present position. The addition of these locations improved the sensitivity analysis and the validation procedure. Since one of the most serious errors that can be made in a multi-attribute model is to fail to include relevant attributes

Table 3
Decision Worksheet

	Attribute	Score					
1.	Leasable Square Footage	-5	-3	-1	+1	+3	+5
2.	Anchors	-5	-3	-1	+1	+3	+5
3.	Type of Mall	-5	-3	-1	+1	+3	+5
4.	Mall Sales per Square Foot	-5	-3	-1	+1	+3	+5
5.	Store Location in Mall	-5	-3	-1	+1	+3	+5
6.	Attitude of Merchants in mall	-5	-3	-1	+1	+3	+5
7.	Prospects for Clustering Stores	-5	-3	-1	+1	+3	+5
8.	Importance of Developer	-5	-3	-1	+1	+3	+5
9.	Trade Population	-5	-3	-1	+1	+3	+5
10.	Other Malls in Area	-5	-3	-1	+1	+3	+5
11.	Competition in Mall	-5	-3	-1	+1	+3	+5
12.	Area Competition in Trade Area	-5	-3	-1	+1	+3	+5
13.	Average Income in Trade Area	-5	-3	-1	+1	+3	+5
14.	Defense Motive	-5	-3	-1	+1	+3	+5

(Huber, 1974), it was decided *a priori* to retain all attributes and use the sensitivity analysis to determine those which should be treated stochastically.

An index was calculated for each store using the scores provided for each existing store, and the stores were ranked by index value. The indexes were then recalculated and the scores re-ranked by setting each attribute first to one extreme (+5) and then the other (-5) while holding all others constant. Two Spearman Rank Correlation tests were run on each attribute using the original rankings as the basis for evaluating the high and low rankings. It had been feared that the variable weights for some of the attributes would cause large shifts in the rankings, but this fear proved to be groundless at a level of significance of 0.05. A chi-square goodness-of-fit test by attribute on the number of stores receiving a positive and negative index, again using the original indexes as the basis, found attributes 1, 2, 3, 7, 9, and 11 to be significant at the 0.05 level of significance. These attributes were chosen as candidates for stochastic treatment. The DM, however, felt there was no uncertainty associated with attribute Number 7, so it remained deterministic in the final model.

To determine the independence of the attributes in the probabilistic phase, a correlation matrix for all attributes for the existing stores was computed.

Attributes 1, 2, 3, 7, and 9 had R values in excess of 0.59, so were looked at more closely. The first three seemed obviously dependent. The quality of the anchors will determine the type of mall; a large mall is more likely to attract quality anchors. The DM felt both 7 and 9 were independent despite the correlation coefficients. The Kolmogorov-Smirnoff and the Median Test variation of the Wilcoxon Signed Rank Tests both supported the null hypothesis (at a significance level of 0.05) that attributes 1, 2, and 3 had the same distribution. Two alternatives were possible to comply with the independence assumptions of the additive model. Either the DM could be asked to evaluate the dependent attributes as if they were independent, or they could be combined into a single attribute and evaluated together. The solution was a compromise. The DM was instructed to evaluate the first three attributes individually, and if the results for the three appeared to differ greatly, he should reevaluate them as a unit and assign the resulting value a weight of 60 (since the weights of the three individual items were 20 each).

The validation of the model involved two separate procedures. In the first, the DM was asked to grade each of the existing locations on a qualitative scale of excellent, very good, good, marginal, poor, or unsatisfactory. These grades were compared with the rankings provided by the model. The top 40 percent in the predicted rankings had grades of "good" or better with four of the top five receiving "excellent" grades. The bottom 25 percent in the rankings had grades no better than "marginal". Most of the deviations were easily explained. For example, one store ranked low by the model but receiving a high grade from the DM was a "row store" in a college town; the model was not designed to capture the relevant information about this location. One store in a mall graded "poor" but ranked in the upper half of the model had been opened primarily on the strength of the developer and defense motives (*viz.* to keep competitors out of the mall). The DM was satisfied that the model passed this test of validity and that the model was capturing his intuition and "gut feeling" effectively.

For the second procedure, a point in the ranking of the present locations was chosen independently of the DM. Above this point it was believed stores should have been accepted and below the point rejected. The DM objected only to the placement of one store labeled as a reject. Upon reflection, he agreed that his objection was based upon current performance of the store, and the ranking was based upon his feelings before the store opened. This particular store had been an experiment involving a radically different layout which he had thought would not be successful. It was also a layout unlikely to be duplicated in other stores despite its subsequent success. As a test of the validity of this cutoff point, the DM was asked to use Decision Work Sheets to evaluate four malls he had pending. Two malls ranked very high, one was marginal above the cutoff and one was marginal below the cutoff.

He ultimately accepted the two that ranked high and the marginal below the cutoff, and he rejected the marginal above the cutoff. When we questioned him on the latter two, it appeared he had upgraded the defense motive on the one he accepted, and downgraded the developer motive on the one he rejected. Based upon the revised scores for these attributes, the positions of the two malls reversed and were consistent with his decision. This experiment emphasized the necessity of reevaluation of prospective malls several times prior to making the final decision. The last step in completing the model was to add a constant to the index to shift the cutoff point between accepting and rejecting a mall to zero.

Implementation

The final step in the project was to assemble an implementation manual for the DM detailing the steps for using the model, interpreting the results, and revising the

model in the future as priorities for the DM and the company changed. Since the DM normally made his decisions while traveling and often had to make decisions on the spot, the system was originally developed as a manual, paper-based system to provide maximum flexibility. This system could easily be adapted to current technology such as a spreadsheet on a notebook, netbook, or tablet-type computer such as an iPad. The DM and the management of the company were pleased with the results and felt that their objectives had been achieved.

Conclusions

The oft-repeated adage in real estate is "location, location, location," and site selection is one of the critical decisions facing any retailer. The decision is complicated by the many different and often conflicting factors that must be considered. Multiple-attribute decision models are a valuable tool to help resolve the problem. This article describes the evolution, evaluation, and application of a scoring model based upon multi-attribute utility theory. Its purpose was to assist the decision maker for a rapidly growing national retail chain to locate new stores. The objective was to model the DM's preferences explicitly and thus increase the efficiency and reliability of the firm's location decisions. Involving the DM throughout the process enabled the

researchers to increase user understanding of and satisfaction with the model.

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