Parameter Estimation in the **Huff Model**

By David L. Huff

Editor's note: *Dr. David L. Huff pioneered several spatial analysis techniques, most notably the Huff Model, which was introduced in 1963 in an article in* Land Economics *entitled "A Probabilistic Analysis of Shopping Center Trade Areas." The model has been used for tasks such as predicting consumer spatial behavior, delineating trade areas, locating retail and service facilities, analyzing market performance, simulating different market scenarios, and forecasting sales.*

The Huff Model has endured the test of time—more than 40 years. Its widespread use by business and government analysts, as well as academicians, throughout the world is remarkable. With the development of GIS, the model has received even more attention.

The model's longevity can be attributed to its comprehensibility, relative ease of use, and its applicability to a wide range of problems. The model is conceptually appealing. Its logical underpinning makes sense, and the output can be communicated easily and understandably. The model is relatively easy to make operational because the necessary computations are straightforward once the values of the variables and the parameters have been specified. Finally, its applicability to a wide range of problems and its ability to predict outcomes that would be difficult, if at all possible, without the model have made its use widespread.

However, despite the general applicability of the model, it has not always been employed correctly and its full potential has not been realized. After a quick review of the model, the remainder of this article will address these two issues.

Review of the Model

The model is based on the premise of the probability that a person confronted with a set of alternatives will select a particular item is directly proportional to the perceived utility of each alternative. Choice behavior can be viewed as probabilistic. As a result, it is unlikely that any given alternative will be selected exclusively unless no other alternatives exist. This proposition can be expressed symbolically as shown in Figure 1. The probability that an individual *(i)* will select the alternative

$$Pij = Uj \Big/ \sum_{j=1}^{n} Uj$$

Figure 1: Choice behavior

(j) given the utility of *j* is relative to the sum of the utilities of all other choices *(n)* considered by individual *(i)*. In order for the model to be applied, the utility of each alternative must be defined empirically.

The first geographic application of the model was an attempt to predict consumer patronage patterns for different classes of products. The utility of a store was defined as the ratio of the square footage of the store's selling area to the distance from a consumer's residence to the store. Each of these variables was weighted by an exponent (i.e., parameter) that was estimated empirically by surveying the shopping preferences of individuals in the study area.

It was posited that the size of the store was more important for some products than others. Consequently, the value of the exponent could be expected to be larger for these products. Conversely, the exponent for distance was assumed to be negative. Convenience products could be expected to have a larger exponent while specialty goods would have a much smaller exponent. The probability that a consumer located at *i* selecting store *j* can be estimated using the formula in Figure 2. In this

$$Pij = Sj^{\alpha}\ Dij^{\beta} \Big/ \sum Sj^{\alpha}\ Dij^{\beta}$$

Figure 2: Consumer store selection

formula, P*ij* is the probability of a consumer located at *i* choosing store *j*. S*j* is the square footage of store *j*; D*ij* is the distance from *i* to *j*; and *a* and *b* are parameters that were estimated based on the actual survey data. This calculation was done using an approximation solution since the application of conventional statistical procedures was considered impossible.

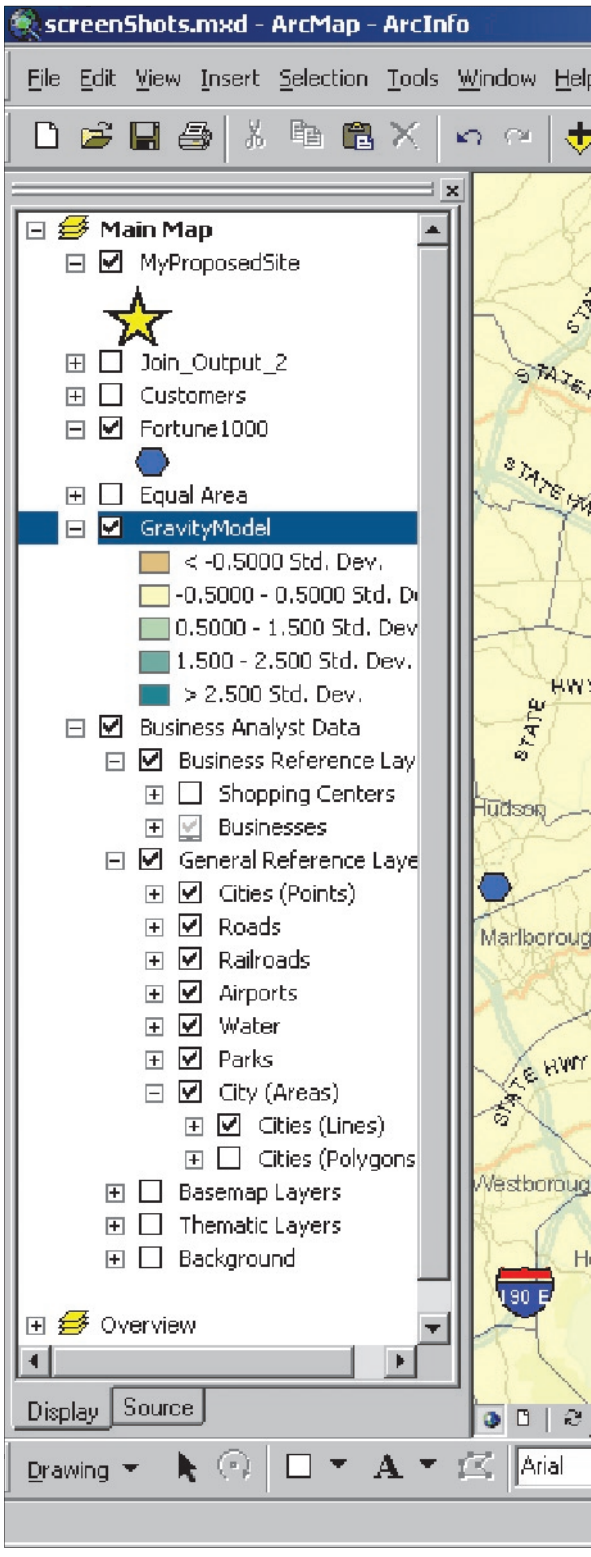
Once the parameters were estimated, not only could the probabilities of patronage be estimated, but also the expected purchases from subareas within the study area as shown in Figure 3. In this scenario, E*ij* is the expected purchases from area i to store *j* and B*ik* is the amount budgeted by consumers in *i* for product *k*.

$$Eij = Pij\ Bik$$

Figure 3: Patronage and purchases

Lack of Statistical Verification

Analysts using the Huff Model typically incorporate some measure of accessibility (e.g., road distance, travel time, cost) as well as a variable that reflects the attraction of a given destination. The weights (i.e., parameters associated with these variables) are often assigned arbitrarily. They are rarely estimated statistically. As a result, the statistical significance of these variables is unknown. Obviously the lack of statistically validated variables and parameters can produce erroneous results. Without an accurate statistical assessment, analysts are using the model to make predictions based



on unverifiable inputs. As a consequence, the results are subject to error.

Why Calibration Is Omitted

There are three reasons why more analysts do not calibrate the model statistically. First, the nonlinear properties of the model are perceived by some users to be much more difficult to calibrate because the model must be linearized with respect to its parameters before standard statistical estimation methods can be applied. A number of researchers, including Lee G. Cooper and Masao Nakanishi (see *Market-Share Analysis: Evaluating Competitive Marketing Effectiveness,* 1988), have been interested in this problem. This has resulted in major breakthroughs that now make it possible to use standard techniques such as ordinary least squares for calibrating the model.

The necessity (and the difficulty) of in-

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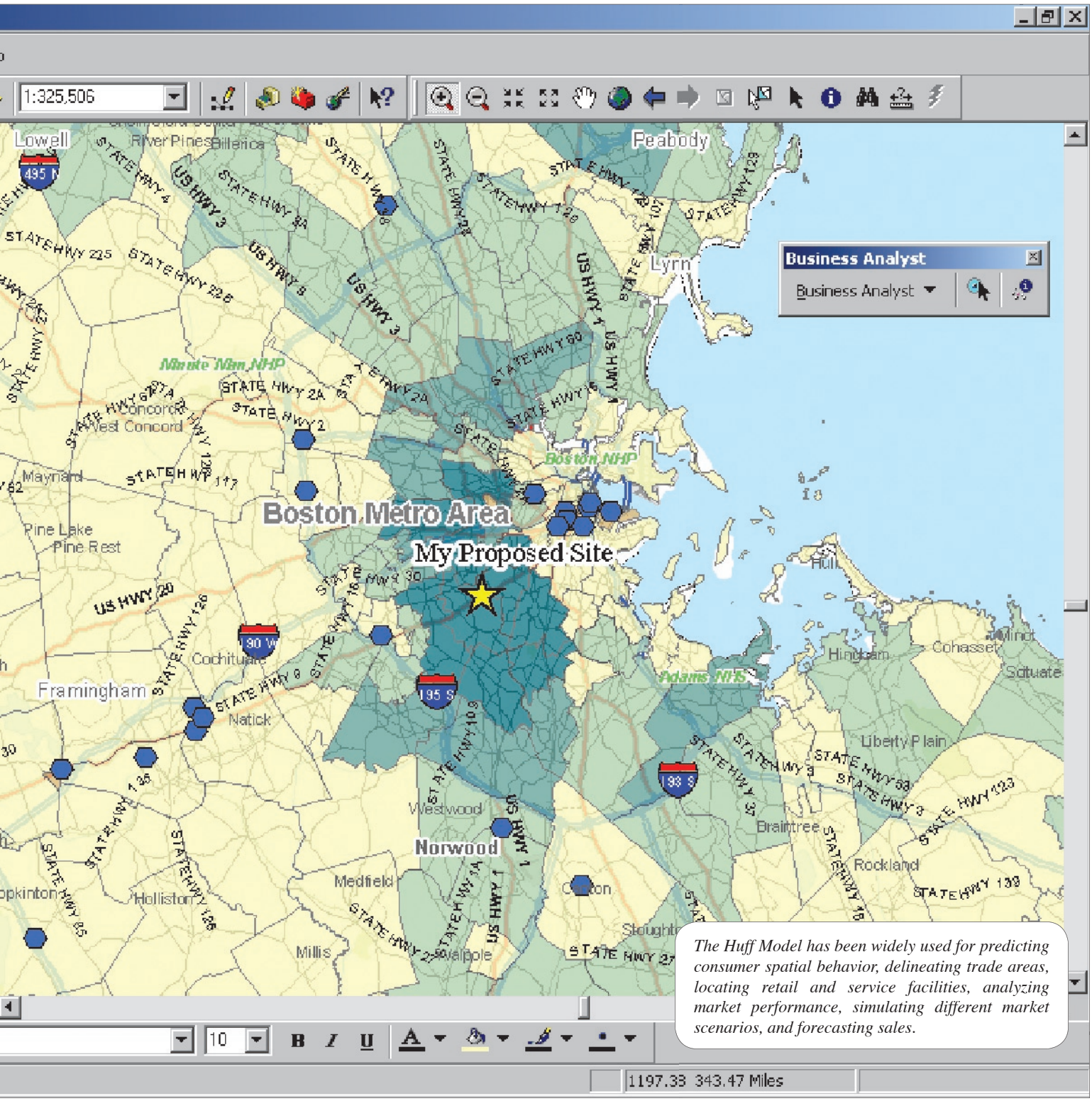

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corporating origin-based data as opposed to destination-based data supplies another reason why the model is often not calibrated statistically. Actual choice behavior (the variable to be predicted) must be obtained empirically from residents of geographic subareas located within some larger study area, and choices must be obtained for all alternatives considered by these residents. Unfortunately, most companies collect data only on their facilities (i.e., destination data). As a result, patronage data for competitors is usually unknown. The task of obtaining actual shopping preferences for different products can be time-consuming, as well as expensive, because it requires surveying at the household level.

The lack of GIS software packages that are equipped for this type of analysis also inhibits the correct application of the model. To perform this type of analysis, the software must

- Be able to execute the necessary operations of the model.
- Include a statistical package that can generate the statistics necessary for assessing the significance of variables used to predict choice behavior and indicating how well the model predicted actual choice frequencies.
- Possess mapping capability that enables analysts to examine errors of prediction as well as other geographic patterns that might be suggested by the data.
- Be designed for use by non-GIS specialists as a decision making tool.

Enhanced Capabilities of the Model

As mentioned previously, many variables in the Huff Model can be included and the associated parameters determined statistically so that the impact of a variety of variables can now be assessed that would not have been possible previously. In general, predictive variables can be classified as being either controllable or noncontrollable.

Controllable variables, such as advertising and promotion, pricing, and store format, can be controlled or influenced by the company. Noncontrollable variables, such as accessibility, population distribution, income, and competition, are typically beyond the firm's control. Traditionally, some of these variables are examined visually on thematic maps or pin maps and subjective conclusions advanced as to the probable impact of these variables. However, being able to examine these variables statistically adds immeasurably to the accuracy of such conclusions.

Increasing Business Usage

Most executives have not been shown how their revenues could increase by investing in software, modeling, and data. An increasing number of executives understand and appreciate the value of thematic maps and address matching and the importance of trade area analysis, customer profiling, and target marketing. This information is ideally suited for display on maps and can be related to without difficulty.

The benefits of modeling are not always recognized by business decision makers—it is different and much more difficult. Decision makers, in general, lack the proficiency to comprehend the technical aspects of model development and use. In addition, most software distributors do not realize that companies do not want to spend money for research and development. What is required to get modeling adopted by more businesses is a logical and defensible cost-benefit analysis of its benefits and an appreciation that the bottom line is what matters in business.

Huff Takes Advisory Role at ESRI

Dr. David L. Huff, an internationally recognized researcher in the spatial aspects of marketing and creator of the Huff Model, has joined the ranks of ESRI technical contributors. As part of his exclusive agreement with ESRI, he will serve as an advisor and use his expertise to develop advanced predictive models and review existing analysis capability in ESRI's business analysis product and service offerings.

Designed to predict consumer spatial behavior, the Huff Model is used extensively by market analysts and planners and has served as the seminal work for others doing research in modeling choice behavior.

As a professor at the University of Texas, Austin, Huff has held a variety of administrative and teaching positions in both geography and marketing and has consulted for dozens of agencies including the United States Department of Transportation; United States Bureau of the Census; the National Institutes of Health; National Endowment for the Arts; Resources for the Future, a nonprofit and nonpartisan think tank; numerous state and regional offices; and hundreds of businesses.

Other research areas that Huff has contributed to include the application of multivariate graphic displays to market analysis, the formulation of objective measures for delineating market areas, the development of computerized systems to monitor economic activities geographically, and the derivation of planning regions for the geographic delivery of health care and economic services.

In 1988, Huff was awarded the James R. Anderson Medal in Applied Geography, the highest honor awarded by the Association of American Geographers for distinguished research in applied geography. He also received the Distinguished Mentor Award from the National Council for Geographic Education in 1998 for his many years helping students pursuing master's and doctoral degrees.