Targeting with the Analytic Hierarchy Process

By

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Background

Each year state and local governments in the US spend millions of dollars to stimulate economic development within their boundaries. Surprisingly, considering the vast amount of money being spent on economic development programs, there is little research examining people's preferences for economic development outcomes, and even less evidence that preferences are considered as economic development programs are planned and executed. The political process is the only means that residents have for expressing their preferences for the future of their communities.

Knowledge of these residents' preferences, if known, could lead to much more proactive, and cost-effective economic development programs. In the absence of articulated preferences, economic development is less likely to have clear objectives. In fact, most policies and programs, if evaluated at all, are measured by numbers of jobs created, the easiest indicator available. But what of other indicators such as the quality of jobs, the stability of the economy, the contributions to the local tax base, the environment, the social structure, etc.?

Community preferences should matter. Economic development outcomes, regardless of the program or policy in question, are felt locally in a number of ways. For example, a new firm creates employment, generates incomes, adds to the tax base, stimulates related businesses, generates demands on public infrastructure and services, creates additional congestion, changes property values, and generates both positive and negative externalities. Evaluating the desirability of these different outcomes depends on their relative magnitudes, and residents' preferences. The result is a form of multi-attribute decision-making problem. The critical information in such a decision-making problem is the weights to attach to the different expected impacts.

This chapter describes a means of incorporating local preferences in industry targeting strategies and gives an example of its application. The approach involves three steps. Local residents are interviewed in the first step, and the analytical hierarchy process (AHP) is used to create cardinal weights for different local impacts of economic development outcomes. In the

second step, the impacts of alternative economic sectors are identified and quantified. The third step involves applying the preference weights to the predicted impacts of each industry to derive a community-specific measure or score for each industry. This chapter focuses on the first step in this process.

Weighting Community Preferences

When development outcomes are multi-dimensional, a means of weighting these dimensions is needed to rank the events that cause the outcomes. If community preferences were known over the K dimensions (types of impacts) of an economic change, then scoring each of the j=1...J industries, on the basis of the set of impacts that it caused, would be straightforward:

$$S = IW^{*} \qquad (1)$$

where S is a $Jx1$ vector of scores for the J industries, I is a JxK matrix of impacts of the j^{th} industry on the k^{th}, and W is a $Kx1$ vector of weights of the K impacts.

Previous economic evaluation systems have been limited by two typical characteristics. First, most attempts to evaluate alternative industries or firms rely on weights applied to the direct impact of the industry or firm - the number of jobs created, wages paid, etc. Few have tried to weight the final impact of the firm - changes in population, change in property values, environmental outcomes, as well as total employment and income effects. For example, Shaffer (1989) recommends use of a screening system where a community assigns weights to the set of firm characteristics. Johnson, et al, (1994) had community members assign weights to a list of screening criteria that were used to identify industries for targeting. These studies focus on the direct attributes of firms and sectors, and do not examine the final impact on the regional economy.

The second major shortcoming of many studies is their reliance on *ad hoc* scoring methods that do not necessarily reflect the preferences of residents. Ad hoc scoring involves using equal weights, or arbitrarily chosen weights with which to collapse several indicators into a

score. This approach is simple, but will not, in general, lead to the same rankings that weights based on residents' preferences would. Alston, et al (1995) criticize scoring methods (in the context of agricultural research) showing that they frequently lack rigor, have no theoretical basis, and are fraught with inconsistencies in assigned weights. They conclude that "weights on objectives should reflect clients' value judgments about trade-offs among objectives (p. 467)."

Methods other than pair-wise comparison as used in the AHP exist to obtain preferences from decision-makers. Ordinal rankings and fixed point scoring are two of the less rigorous methods available. Other preference elicitation methods include the Delphi technique, the multi-attribute utility procedure, and the Clarke-Groves voting procedure (Cohon, 1978, Harker, 1989, Romero and Rehman, 1987, Tideman and Tullock, 1976)[1].

The Delphi technique obtains preferences (weights) from decision-makers through anonymous questionnaires, controlled feedback, and statistical analysis of the results (Dalkey, et al, 1972). Each person ranks the criteria using a scale of importance and explicitly states her underlying assumptions. The ranking is accomplished using an ordinal scale (i.e. 1 = very important, 2 = moderately important, etc.). The assessments and assumptions of the group members are analyzed, medians and quartiles are calculated, and the results distributed to the group. Each member then has the opportunity to revise her earlier assessment, based on the results of the group. This process is repeated until a consensus has been reached (Hampton, et al, 1973).

The multiple-attribute utility procedure requires the decision-maker to answer questions dealing with probabilities, usually in a lottery framework (Roberts, 1979). Decision-makers are asked to predict the probability of a particular consequence (criterion). As the probabilities being

[1] For a more detailed description of these and other methods used to support multi-criteria decision-making, see Romero and Rehman (1987), Hampton, Moore, and Thomas (1973) and Roberts (1979). For an evaluation of group decision making methods, see Srisoepardani
http://www.expertchoice.com/support/ahpcompare/chapter6.htm.

elicited are usually subjective in nature, they "represent the 'degree of certainty' or 'degree of conviction' that the expert has that an event will occur (Roberts, 1979, p. 372)." The outcomes derived from the probabilities represent the utility (weight) of each criterion.

The Analytical Hierarchy Procedure

The AHP, developed by Saaty, is a means of weighting or prioritizing outcomes of a choice when several considerations are relevant. Through pair-wise comparisons of several outcomes, the relative importance, or weights, of different factors can be measured; tradeoffs between objectives are explicitly considered in these pair-wise comparisons. The pair-wise comparison process imposes rigor that is missing when directly assigning weights to a number of impacts, because possible inconsistencies (intransitivity and inconsistent weights) in the judgments can be calculated and reexamined. Even with subjective criteria, the weights obtained through the AHP are “ratio scale numbers and correspond to so-called hard numbers (Saaty and Kearns, 1985, p. 19).” Thus, the derived priority weights are cardinal.

AHP has been applied to a variety of issues, including electric utility planning, portfolio management, conflict management, advertising, and resource allocation (for examples, see Hämäläinen Seppäläinen, 1986; Lauro and Vepsalainen, 1986; Saaty and Alexander, 1989; Dyer, et al, 1992; Saaty, 1980).

Structuring the Problem

The first step in the AHP is to decompose the problem into a dominance hierarchy (figure 1). The top-most level represents the goal or focus of the problem. Intermediate levels are the criteria on which lower levels depend, and the lowest level is the list of choices or alternatives (Saaty and Kearns, 1985). As many levels as necessary can be used. The lower levels act as the criteria or factors contributing to the level immediately above (see Saaty and Kearns, 1985 for applications of AHP). In the context of the economic development problem, the goal might be

the overall enhancement of regional quality of life, and the criteria might be the industry impacts (such as total local jobs created or measured change in environmental quality following the industry location). The alternatives would be the firm or industry types.

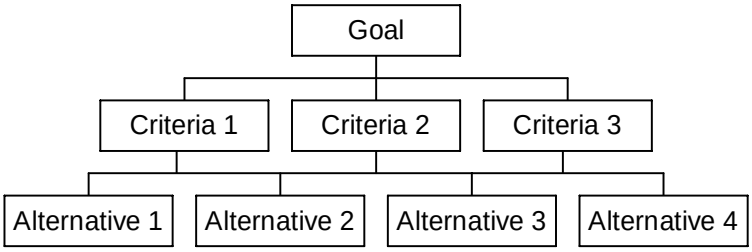

Figure 1. Generic Decomposition of a Problem into A Dominance Hierarchy

Pairwise Comparison

Once the problem is decomposed into a hierarchy, each element must be compared to other elements at that same level. The questions asked for the second level could take the form, "When comparing different criteria, which criterion is more important (in achieving the goal)?" Other kinds of questions that could be asked include: "When comparing A and B, 'Which is more important?' 'Which has a greater impact?' 'Which is more likely to happen?' and 'Which is more preferred?'" (Saaty and Kearns, 1985). The nature of the question depends on the desired outcome and the level being compared.

Judgments from these pair-wise comparisons are entered into a KxK square matrix P, with a column and a row for each criterion. The p_{ij} element is the numerical answer to the question "With respect to the goal, what is the importance of criterion i versus criterion j?" The matrix is reciprocal, with K(K-1)/2 pair-wise comparisons, $p_{ij} = 1/p_{ji}$, and $p_{ii} = 1$. If criterion i is more important than criterion j, the cardinal scale value representing the intensity is entered

directly into the matrix position p_{ij}. However, if criterion j is more important than criterion i, the *reciprocal* of the scale value representing the intensity is entered into the matrix position p_{ij}.

If the actual utility weights of the criteria being compared were known, the p_{ij} would represent the ratio of the weights:

P = **W,** (2)

Where $w_{ij} = w_i / w_j$ and w_i is the utility weight of the i^{th} criterion (see equation 1). When the weights $(w_1, w_2, ..., w_K)$ are unknown, then the pair-wise comparison is performed using subjective judgments estimated numerically from a scale of numbers. The scale recommended by Saaty (1977) has been validated for effectiveness in different applications (table 1).

Solving for Preference Weights

Obtaining the relative weights would be simple if there were no errors or inconsistencies in comparisons. In such a case, **W** could be solved as an eigenvector of **P** corresponding to an eigenvalue equal to K, which, in the perfectly consistent case, is also the matrix rank (Saaty, 1980):

, (3)

where **P** is the comparison matrix, **w** is the eigenvector corresponding to K, and K is the number of rows and columns of **P**, or, in other words, the number of impacts being assigned weights.

In general, the **P** matrix will contain errors or inconsistencies. The inconsistencies can be attributed to the limitations put on the comparison by the scale being used. That is, each p_{ij} is based on subjective estimates, not on exact measurement. The judgment matrix is not an exact ratio of w_i / w_j, but rather, a ratio of integers used to scale preferences which can lead to significant rounding error (Fichtner, 1986).

Table 1. Scale of Relative Importance

Intensity of Relative Importance	Definition	Explanation
1	Equal importance.	Two activities contribute equally to the objective.
3	Moderate importance of one over another.	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance.	Experience or judgment strongly favors one activity over another.
7	Demonstrated importance.	An activity is strongly favored and its dominance is demonstrated in practice.
9	Extreme importance.	The evidence favoring one activity over another is of the highest possible order of affirmation.

Source: Saaty and Kearns, 1985

Human error can also lead to inconsistency. The process of making pair-wise comparisons can itself lead to changing estimation of ones preferences as more thought is given to the alternatives. Prior rankings of each pair of elements are difficult for people to consider as they compare new alternatives. This limitation is the primary reason for keeping the number of elements to be compared at each level of the hierarchy below nine (see Saaty, 1980). Given the inevitability that there will be inconsistencies in the comparisons, the maximum eigenvalue is used in place of K to solve for **w**:

, (4)

where λ_{max} is the maximum eigenvalue of **P**, and **w** is the eigenvector corresponding to λ_{max}. Weights are calculated using the eigenvector corresponding to the largest eigenvalue, λ_{max}. The elements of **w** are normalized using:

$$w_i^* = w_i \Big/ \sum w_i \quad (5)$$

These results (w_i^*) are the cardinal, or relative, values (weights) of the criteria. The vector of these weights W^* is used in equation 1.

A strength of the AHP is its ability to estimate preference weights even when there is some degree of intransitivity among criteria and inconsistency in the intensity with which judgments are expressed. The AHP provides a way for inconsistencies to be measured. It is desirable for judgments to fall under a given consistency threshold.

Applying AHP to Targeted Regional Economic Development: A Case Study

One of the earliest applications of the AHP to regional industrial targeting was Cox et al (2000). The AHP was used to measure preferences by the development directors and other local leaders for alternative development outcomes in three Virginia counties.

The overall goal in the hierarchy was to maximize total quality of life in the locality. The second level goals included the various types of impacts that a firm can have on a locality. Following a review of findings from other studies, and a survey of economic development directors in the state of Virginia (Bailey, 1996), the following impacts were identified[2]: number of jobs created, average wage or salary, average level of capital investment, average level of utility requirements, environmental impacts, effect on population growth, and impact on property values.

The number of newly created jobs was often highlighted as an indication of success in economic development but localities were also reported to be interested in job quality and the average wage or salary is an indicator of quality. Capital investment is important because it shows commitment to the community, and it increases the stream of property tax revenues.

[2] Economic Development directors were surveyed by Bailey to understand which firm attributes made the firm likely to receive an incentive package. Bailey's results were used to define the universe of plausible firm impacts on the community and are not assumed to reflect "community values."

In addition the water and sewer requirements of new firms were included because of the potential for utility capacity constraints (Bailey, 1996). Property values were important to the local government primarily because increased property values increase the tax base. The perceived cleanliness of industry was included to determine the importance of environmental considerations to decision-makers in these communities. Finally, the impact of population growth is a measure of several of the "costs" associated with economic development, such as congestion.

AHP Interview and Results

The counties in this Cox et al study were chosen because they were broadly representative of county types in rural Virginia. One county is heavily dependent on natural resource-based tourism. It also faces economic stagnation and contains a relatively high proportion of poor households. The second county is a mixed agricultural-manufacturing. The third county has grown rapidly in recent years and faces challenges of growth management.

Local government and business leaders were invited to participate in the industry ranking process as representatives of their county. While it was recognized that the preferences of other county residents may vary from those invited to participate, local leaders' involvement in the community were thought to provide a broad, comprehensive view of the issues and constraints facing their county.

Participants were asked to consider every possible combination of two impacts, "When comparing impact A to impact B, how important was one over the other with respect to the attractiveness of an industry?" If there was immediate consensus, that judgment was entered into the matrix. If not, a discussion of the assumptions or considerations each individual used when making his or her value judgment ensued. At the end of the discussions, a person would be convinced enough to change his judgment or the group would agree on a compromise.

Calculation and Reevaluation of the Comparison Matrix

When the initial judgment matrix was filled, the priority outcomes were calculated as described above. The consistency ratio was calculated. If the consistency ratio (CR) was above the threshold of 0.2, the judgment matrix was reexamined. Reevaluation did not mean that respondents were forced to accept prioritization with which they disagreed; rather reevaluation allowed respondents to review their choices and to ensure that no blatant inconsistency existed. For instance, if environmental quality is strongly favored to number of jobs and number of jobs is strongly favored to capital investment, then environmental quality should also be strongly favored to capital investment. Respondents discussed the inconsistencies. They then identified which rankings or weights that did not make sense to them. This led the group to analyze their judgments and further discuss the assumptions behind the judgments. This process was repeated until the CR was lower than 0.2 and participants were satisfied that the ranking and weights adequately represented their preferences.

Results of AHP

Experience with the interviews varied by county, but the priority weightings and rankings were reasonably consistent across counties. For two out of the three counties, reexamining the pair-wise comparisons was necessary due to initial inconsistencies in the judgment matrix. The rankings are shown in table 2. Differences in rankings highlight the location-specificity of development preferences; different counties have different preferences.

Table 2. Final Ranking and Weights by Impact, Three Virginia Counties

	County One		**County Two**		**County Three**	
Rank	**Impact**	**Final Weight (%)**	**Impact**	**Final Weight (%)**	**Impact**	**Final Weight (%)**
1	Cleanliness of Industry	51	Cleanliness of Industry	49	Average Wage or Salary	35

2	Average Wage or Salary	16	Level of Capital Investment	23	Cleanliness of Industry	24
3	Impacts on Property Values	13	Average Wage or Salary	13	Level of Capital Investment	16
4	Number of Jobs	6	Number of Jobs	6	Number of Jobs	12
5	Level of Capital Investment	5	Impacts of Population Growth	5	Impacts of Population Growth	7
6	Level of Utility Requirements	5	Level of Utility Requirements	3	Impacts on Property Values	4
7	Impacts of Population Growth	4	Impacts on Property Values	2	Level of Utility Requirements	2
CR		.196		0.275		.142

Preferences for Outcomes

Participants in all three counties had a strong preference for a clean environment. Environmental quality was ranked a strong first in 2 out of 3 of the counties and it finished second in the third (table 2). County one's desire to maintain an attractive environment is probably due to the county's heavy reliance on tourism. County two, on the other hand, has aggressively recruited industry for more than a decade, and the high weight placed on industry cleanliness might be due to their experience with industries that were less than ideal in this regard. Decision-makers expressed the view that "smokestack chasing" was a strategy of the past. In both counties, environmental quality received more than double the weight of the next-preferred outcome.

In this study, the number of jobs associated with a development event was substantially less important than cleanliness of the firm and quality of jobs. This outcome was ranked only 4th

most important in each county, with a weight ranging from 12 percent to about 6 percent. In all counties, number of jobs is an important consideration, but job quality and environmental quality rank higher. County one's respondents reasoned that although their unemployment rate was higher than the state average, the number of unemployed is small because of their small population. It is thus not essential to create large numbers of jobs locally.

Average wage or salary was the most important consideration for county three, with a priority weight of 35 percent. Participants felt firms offering higher pay were more attractive since the county has an educated work force, and decision makers sought to increase the number or "head of household" type jobs. Decision-makers in the other two counties ranked average wages highly, and stated directly their belief that higher pay is associated with a higher quality job. Respondents in county two reasoned that the county had made great strides recently in increasing the number of jobs locally, and that it was time to focus on job quality over quantity. Respondents in all counties valued the contribution of the development event to the local tax base. Capital investment is ranked second in county two (24 %) and third in county three (16%). Participants considered tax revenues associated with higher capital investment to be important. Firms with large capital investments were also believed to be less likely to relocate in the future. In contrast, county one's respondents argued that the best way to effect increases in property tax revenues was by increasing local property values. They put a low weight on capital investment, reasoning that capital investment was associated with heavy industry, and such industry might damage the tourism base of the economy.

Respondents in two counties placed low weights on changes in property values. Impacts on utility requirements and population changes received low priority weights in all counties. In county one, utility requirements received a relatively low score because water, sewer, and electricity use are currently far below capacity. In the other counties, respondents decided that if a firm had desirable characteristics, the county would expand its sewer and water capacity to meet industry needs.

The impact of population growth was somewhat important to the respondents from county three (7%), primarily because of the potential increase in traffic, and the resulting congestion occurring in the past several years. In two counties, respondents decided the schools, roads, and other facilities are more than adequate for the current population. In all counties, population increases were not viewed favorably, but in the latter two counties such increases were accorded small weights.

Scoring the Impacts

The *level* of each type of impact associated with each industry was calculated for each county. Industry scores for all counties are found in Cox (1996). Scored impacts were multiplied by the priority weights to calculate the adjusted score for each industry and the county-specific rankings of each industry. The scores are reported for one county in table 3.

Community preferences used as priority weights have a strong effect on the ranking of industries.

Rank	Sector Name	Average Number of Jobs (per million output)	Average Wage or Salary ($/year)	Value-Added Effect (total VA/$ output)
1	Pipe Lines, Excluding Natural Gas	2	$ 58,113	0.9011
2	Railroads & Related Services	8	$ 61,152	0.7776
3	Communications, Except Radio & TV	6	$ 49,516	0.9074
4	Electric Services	3	$ 54,112	0.7027
5	Computing & Data Processing	13	$ 33,780	0.9108
6	New Government Facilities	10	$ 36,410	0.7366
7	Oil & Gas Wells Maintenance & Repair	27	$ 21,658	1.1702
8	Electronic Computers	6	$ 63,525	0.7947
9	Federal Government - Non-military	21	$ 47,933	1.1401
10	Distilled Liquor, Except Brandy	2	$ 57,072	0.9805
11	Research, Development & Testing	24	$ 27,336	0.9992
12	State & Local Electric Utilities	4	$ 44,098	0.7019
13	Wholesale Trade	13	$ 36,095	1.0206

14	Other Business Services	21	$ 16,709	0.9860
15	Arrangement Of Passenger Transportation	22	$ 20,393	0.9595
16	Transportation Services	13	$ 29,108	0.7744
17	State & Local Government, Non-education	32	$ 31,637	1.3026
18	Fluid Power Pumps & Motors	18	$ 46,088	1.1166
19	Residential Maintenance & Repair	13	$ 23,717	0.7337
20	U.S. Postal Service	18	$ 42,275	0.8909

Environmental quality, as shown earlier, has a major effect on industry rankings. None of the top 9 and only 2 of the top 20 industries in Table 3 had any adverse environmental impact. The top sectors are those with relatively low impacts on the environment and relatively high wages (Distilled Liquor, except Brandy; Federal Government, non-military). All of the top industries in Table 3 are highly linked to the local economy, and have favorable overall impacts.

The most preferred industry for all counties is Pipelines, Excluding Natural Gas (table 4). This industry had high average wages, represented the largest proportional capital investment, and had no adverse environmental impact.

Summary and Conclusions

Economic development is rarely a controversial goal in general. However, growth in economic activities (either new firms or expansion of existing firms) can have very different outcomes depending on the specific types of economic activities that locate or expand in a region. Diversity among individuals leads to differences in preferences for these outcomes. These differences in preferences mean that policy makers at local and state levels cannot assume they know what the best economic development policies will be until they have explored these preferences with residents. Preference elicitation and the incorporation of these preferences is a critical part of targeting. The AHP gives policy makers a way to have residents communicate their preferences for economic, social, environmental and other outcomes of economic development policy.

The diversity of preferences extends to different communities as well, ensuring that different policies will be appropriate in different communities. Cox et al found quite different preferences and resulting differences in targeted industries among three rural communities in Virginia. People vote with their feet which, over time, can lead to quite different community level preferences.

Of course, in order to take advantage of the weights determined with this approach, policy makers much have information on the differential impacts of firms or industries in terms of the dimensions identified in the AHP process. These issues are addressed elsewhere in this volume.

Overall, including community preferences through the AHP promises to be a valuable tool for targeting regional economic development efforts. It accommodates the diversity of values among people and of the resulting differences among communities. AHP provides a means choosing among multiple alternatives while accommodating multiple objectives and multiple decision-makers.

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