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The allocation of intangible resources: the analytic hierarchy process and linear programming

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Abstract

An intangible is an attribute that has no scale of measurement. Intangibles such as effort and skill arise in conjunction with resource allocation but are not usually included directly in a mathematical model because of the absence of a unit of measurement. However, intangibles can be quantified through relative measurement (priorities). Intangible resource allocation uses these priorities along with normalized measures of tangibles (when present) in a linear programming model with coefficients and variables measured in relative terms. The priorities of tangible resources from the optimal solution can then be used to assign monetary values to priorities of any intangible resources.

Keywords: Intangible resources; Resource allocation; Analytic hierarchy process; Priorities; Relative measurement

1. Introduction

Intangible resources such as quality, care, attention, and intelligence are often needed to develop a plan, design a system or solve a problem. Thus far, resource allocation models have not dealt with intangibles directly, but rather by assigning them worth in terms of such phenomena as time and money. Our goal in this paper is to show that, although there is no direct scale of measurement for an intangible, it can be measured in relative terms together with tangibles. A ratio scale of priorities can thus be derived for both. These priorities serve as coefficients in an optimization framework to derive relative amounts of resources to be allocated. For intangible resources, because there is no unit of measurement, no absolute amount of a resource can be specified. However, in the presence of tangibles, it becomes possible to compute their absolute equivalents because of the proportionality inherent in their priorities.

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Our concern with the measurement of intangibles relates to the value of assets owned by corporations. While one may argue that the market value of a company, including its intangible resources, is concretely calculated from its tangible assets, intangibles become particularly significant when, for example, two companies merge, and synergy gives rise to new intangibles with potential positive and negative impacts on the value of the combined company. Measuring such intangibles could help assess the wisdom of a merger. An example given later in the paper illustrates this point.

2. On the measurement of intangibles

Webster's unabridged dictionary defines a tangible as something "conceived or thought of as definable or measurable," and an intangible as something "incapable of being defined or determined with certainty or precision." Thus, measurement is central in transforming an intangible into a tangible. A scale of measurement requires a unit. A unit is the single most important building block on which a scale is found. Measurement on a scale involves the numerical assignment of multiples and fractions of the unit of that scale. A scale is a set of objects, a numerical space and a mapping from the objects to the numbers invariant under some transformation. To construct a mapping *consistently* so that, for example, objects having more of the attribute being measured are assigned larger values, one must compare each new object with one or more objects for which measurements are already known. Clearly, this process begins by adopting a smallest object to serve as a unit for the comparisons. Thus, it appears that comparison and experience are an integral part of measurement.

2.1. Relative measurement

In order to measure intangibles, we need comparisons made by someone—an expert—who has experienced different amounts of the quality that characterizes the intangible. Because there is no scale, these comparisons must be made in relative terms. To see how this can be done, and to ensure that results are credible and valid, we first illustrate the approach with a tangible attribute, the area of several geometric figures. Fig. 1 gives five geometric figures that we wish to compare according to area.

To compare two figures in terms of their areas, one first determines which of the two is the smaller, and then estimates the larger in terms of multiples of the smaller. The results of such comparisons across figures are arranged in a matrix $\boldsymbol{A} = \{a_{ij}\}$. If the area of figure i is a_{ij} times larger than the area of figure j, then the area of figure j is $a_{ji} = 1/a_{ij}$ times larger than the area of figure i, a reciprocal relationship. The matrix for these comparisons, the derived scale of relative values (priorities), and the relative values obtained from actual measurement are shown in Table 1. Later, we show how the priorities are derived from the comparisons. Each area represented on the left of the matrix is compared with each area at the top of the matrix to determine how many times it is larger or smaller than that area. For example, Fig. 1A is nine times larger in area than Fig. 1B.

A more abstract form of comparison would involve elements with tangible properties that one must think about, yet cannot be perceived through the senses. Consider a second example: A