

5. *Develop subjective probabilities for each alternative.* We estimate the probability of occurrence of each opportunity ( $p_{u_j}^m$ ) and threat ( $p_{t_j}^m$ ) for each alternative. Subjective probabilities are commonly used in strategic decision making since they require no historical data (observation of regularly occurring events by their long-run frequencies) [13] [46] [47] [56] [57]. Subjective probabilities can be measured by asking a DM for the odds on an event. Various techniques exist to improve subjective probability judgments. One approach uses probabilistic phrases such as impossible, possible, likely, and certain to elicit the required information, and then converts these non-numeric estimates into numeric probabilities [5] [6]. In another simple approach known as reasoning, the DM is asked to list the reasons why he/she believes an event may turn out one way versus another [30]. A related approach is scenario construction which examines reasons or events in combination. By constructing detailed scenarios, a DM is more likely to stretch his/her confidence ranges [46]. A more sophisticated approach is cross-impact analysis. Cross-impact analysis is recommended for calibrating the initial subjective probabilities if the DM believes that there is a high degree of interaction among the environmental factors. Once the probability of occurrence for each factor is estimated, the DM develops conditional probabilities to capture the interactions among these factors. These conditional probabilities are estimated in response to the question, "If one factor occurs, what is the new probability of the second factor?" Stover and Gordon [53] present a complete and step-by-step treatment of cross-impact analysis.

It is assumed that the subjective probability of realizing a situation is binomial. The properties of binomial probabilities are used for calculating the risk-adjusted strategic value associated with each potential alternative. Binomial probabilities are commonly used in strategic decision making because the DM can simplify the problem by analyzing possible outcomes as either occurring or not occurring. For example, Schoemaker [46, p. 206] assigns binomial probabilities to factors such as "U.S. economic GNP growth of at least 4% per annum by the end of 1990" or "Short-term interest rates exceeding 13% in the U.S.A. sometime during the next 5 years." Vickers [56, p. 798] also assigns binomial probabilities to similar factors such as, "A speed limit is imposed upon the German four lane highways" and "Japanese car manufacturers gain at least 30% of the European market share" in order to examine the future of European automobile industry.

In SAM, AHP is not used for this step for two reasons. First, we are interested in capturing the probability of occurrence rather than relative weights of the factors. Second, we wish to avoid the effort required to complete all pairwise comparisons in large hierarchies [32] [58].

6. *Calculate the overall importance weight for the opportunities and threats.* SAM views decision making as an information processing task and a large amount of information about the strategic alternatives is processed through their opportunities and threats. Given the fact that opportunities and threats are information sources, the more information is revealed by the  $j$ th factor in the  $i$ th environment, the more relevant is the factor in the decision analysis. Zeleny [60] argues that this intrinsic information must be used in parallel with the initial weight assigned to various factors by the DM. In other words, the overall importance weight of an opportunity,  $\hat{F}_{u_j}$ , is directly related to the intrinsic weight,  $F_{u_j}$ , reflecting average

intrinsic information developed by a set of alternatives, and the subjective weight,  $W_{u_{ij}}$ , reflecting the subjective assessment of its importance rendered by the DM. The probabilities of occurrence are used to measure this average intrinsic information. The more different the probabilities of a factor are for a set of alternatives, the larger is the contrast intensity of the factor, and the greater is the amount of information transmitted by that factor. In this section, all formulas necessary for calculating the overall importance weight of opportunities are presented. However, this procedure is identical for the calculation of the overall importance weight of threats.

Assume that vector  $p_{u_{ij}} = (p_{u_{ij}}^1, \dots, p_{u_{ij}}^q)$  characterizes the set  $P$  in terms of the  $j$ th factor in the  $i$ th environment and define:

$$P_{ij} = \sum_{m=1}^q p_{u_{ij}}^m \quad \text{for } i = 1, \dots, 3 \text{ and } j = 1, \dots, N_{u_i}. \quad (1)$$

Then, the entropy measure of the  $j$ th opportunity factor in the  $i$ th environment is:

$$e(p_{u_{ij}}) = -K \sum_{m=1}^q \frac{p_{u_{ij}}^m}{P_{ij}} \ln \frac{p_{u_{ij}}^m}{P_{ij}}, \quad (2)$$

where  $K > 0$ ,  $\ln$  is the natural logarithm,  $0 \leq p_{u_{ij}}^m \leq 1$ , and  $e(p_{u_{ij}}) \geq 0$ . When all  $p_{u_{ij}}^m$  are equal for a given  $i$  and  $j$ , then  $p_{u_{ij}}^m/P_{ij} = 1/q$ , and  $e(p_{u_{ij}})$  assumes its maximum value, which is  $e_{\max} = \ln q$ . By setting  $K = 1/e_{\max}$ , we achieve  $0 \leq e(p_{u_{ij}}) \leq 1$ . This normalization is necessary for meaningful comparisons. In addition, the total entropy is defined as:

$$E = \sum_{j=1}^{N_{u_i}} e(p_{u_{ij}}). \quad (3)$$

The smaller  $e(p_{u_{ij}})$  is, the more information is transmitted by the  $j$ th opportunity factor in the  $i$ th environment and the larger  $e(p_{u_{ij}})$ , the less information is transmitted. When  $e(p_{u_{ij}}) = e_{\max} = \ln q$ , the  $j$ th opportunity factor in the  $i$ th environment is not transmitting any useful information. Next, the intrinsic weight is calculated as:

$$F_{u_{ij}} = \frac{1}{N_{u_i} - E} [1 - e(p_{u_{ij}})]. \quad (4)$$

Since  $F_{u_{ij}}$  is inversely related to  $e(p_{u_{ij}})$ ,  $1 - e(p_{u_{ij}})$  is used instead of  $e(p_{u_{ij}})$  and normalized to make sure  $0 \leq F_{u_{ij}} \leq 1$  and

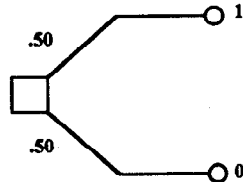
$$\sum_{j=1}^{N_{u_i}} F_{u_{ij}} = 1.$$

The more different the subjective probabilities  $p_{u_{ij}}^m$  are, the larger  $F_{u_{ij}}$ , and the more important the  $j$ th opportunity factor in the  $i$ th environment is. When all the subjective probabilities  $p_{u_{ij}}^m$  are equal, then  $F_{u_{ij}}=0$ . In order to calculate the overall importance weight of the  $j$ th opportunity factor in the  $i$ th environment,  $\hat{F}_{u_{ij}}$ , the intrinsic weight,  $F_{u_{ij}}$ , is multiplied by the subjective weight,  $w_{u_{ij}}$ , and then the product is normalized:

$$\hat{F}_{u_{ij}} = \frac{F_{u_{ij}} \cdot w_{u_{ij}}}{\sum_{j=1} F_{u_{ij}} \cdot w_{u_{ij}}} \quad (5)$$

This procedure is not employed to adjust the weight assigned to each environment, because the average intrinsic information transmitted to the DM through the  $i$ th environment cannot be measured.

7. *Measure the DM's risk-aversion constant for the opportunities and threats.* Assuming the DM is averse to risk and his or her utility function is exponential, the DM's risk-aversion constant ( $r$ ) is calculated for each opportunity ( $r_{u_{ij}}$ ) and threat ( $r_{t_{ij}}$ ). Certainty Equivalence (CE), Probability Equivalence (PE), Gain Equivalence (GE), and Loss Equivalence (LE) are among the various techniques that could be used to measure the risk-aversion constant [22]. We prefer using CE as it is suggested by Bodily [4]. According to CE, the DM is offered the following gamble:



where 1 represents the occurrence and 0 represents the non-occurrence of an opportunity or threat. Given the expected value of  $.50(1)+.50(0)=.50$  for the above lottery, the DM is asked to provide his or her CE between 0 and .50. CE=0 represents complete risk-aversion ( $r=\infty$ ) while CE=.50 represents complete risk-neutrality ( $r=0$ ). Assuming CE is equal to  $p$  and the DM's utility function is given by  $u(p)=1/r(1-e^{-rp})$ , the value of  $r$  that satisfies the given CE using  $e^{-rp}-.5e^{-r}=.5$  can be found. This equation is derived by setting the utility of the CE,  $u(p)=1/r(1-e^{-rp})$ , equal to the expected utility of the lottery,  $Expected\ Utility=.5u(1)+.5u(0)$ . It is always recommended to use more than one kind of question or approach to assure that the risk-aversion constant represents the feelings of the DM.

8. *Calculate the risk-adjusted strategic value for each alternative.* Assuming an exponential utility function for the DM, SAM was developed using Gupta and Cozzolino's [20] formula for the risk-adjusted value of a binomial distribution. The

details of the model are presented in the next section. An exponential utility function was used because it is the simplest model of risk-aversion, and the risk-adjusted value is not a function of the DM's wealth [20]. The risk-adjusted strategic value of an alternative ( $V^m$ ) is a measure of the attractiveness of the alternative calculated by adding the risk-adjusted opportunity value of the alternative ( $U^m$ ) to the risk-adjusted threat value ( $T^m$ ). It should be noted that the positive opportunities and negative threats result in  $1 \geq U^m \geq 0$ ,  $0 \geq T^m \geq -1$ , and  $V^m = U^m + T^m$ . These two values are in turn calculated by summing the multiplication of the relative weight of each type of environment to the relative weight of each factor within that environment and the risk-adjusted value associated with the probability of occurrence of that factor for the selected alternative. Given a DM's risk-aversion constant, the higher the risk-adjusted strategic value, the more attractive an alternative will be.

### The Algebraic Model

To formulate an algebraic model of SAM, let us assume:

- $V^m$  = Total weighted risk-adjusted strategic value of the  $m$ th strategic alternative, ( $m=1, 2, \dots, q$ ),
- $U^m$  = Total weighted risk-adjusted opportunity value of the  $m$ th strategic alternative, ( $m=1, 2, \dots, q$ ),
- $T^m$  = Total weighted risk-adjusted threat value of the  $m$ th strategic alternative, ( $m=1, 2, \dots, q$ ),
- $W_{u_i}$  = The  $i$ th environment weight for opportunities, ( $i=1, 2, \text{ and } 3$ ),
- $W_{t_i}$  = The  $i$ th environment weight for threats, ( $i=1, 2, \text{ and } 3$ ),
- $\hat{F}_{u_{ij}}$  = The overall importance weight for the  $j$ th opportunity factor in the  $i$ th environment, ( $j=1, 2, \dots, N_{u_i}$ ; and  $i=1, 2, \text{ and } 3$ ),
- $\hat{F}_{t_{ij}}$  = The overall importance weight for the  $j$ th threat factor in the  $i$ th environment, ( $j=1, 2, \dots, N_{t_i}$ ; and  $i=1, 2, \text{ and } 3$ ),
- $p_{u_{ij}}^m$  = The  $m$ th probability of occurrence of the  $j$ th opportunity factor in the  $i$ th environment, ( $m=1, 2, \dots, q$ ;  $j=1, 2, \dots, N_{u_i}$ ; and  $i=1, 2, \text{ and } 3$ ),
- $p_{t_{ij}}^m$  = The  $m$ th probability of occurrence of the  $j$ th threat factor in the  $i$ th environment, ( $m=1, 2, \dots, q$ ;  $j=1, 2, \dots, N_{t_i}$ ; and  $i=1, 2, \text{ and } 3$ ),
- $N_{u_i}$  = Number of opportunity factors in the  $i$ th environment, ( $i=1, 2, \text{ and } 3$ ), and
- $N_{t_i}$  = Number of threat factors in the  $i$ th environment, ( $i=1, 2, \text{ and } 3$ ).

Assuming that  $i=1$  through 3 represent the internal, task, and general environments, respectively, the risk-adjusted strategic value for the  $m$ th strategic alternative is:

$$V^m = U^m + T^m, \quad (6)$$

where

$$U^m = \sum_{i=1}^3 W_{u_i} \left( \sum_{j=1}^{N_{u_i}} \hat{F}_{u_{ij}} \left[ -\frac{1}{r_{u_{ij}}} \ln (1 - p_{u_{ij}}^m + p_{u_{ij}}^m e^{-r_{u_{ij}}}) \right] \right), \quad (7)$$

$$T^m = \sum_{i=1}^3 W_{t_i} \left( \sum_{j=1}^{N_{t_i}} \hat{F}_{t_{ij}} \left[ -\frac{1}{r_{t_{ij}}} \ln(1 - p_{t_{ij}}^m + p_{t_{ij}}^m e^{r_{t_{ij}}}) \right] \right), \quad (8)$$

and

$r_{u_{ij}}$  = the DM's risk-aversion constant for the  $j$ th opportunity factor in the  $i$ th environment, and

$r_{t_{ij}}$  = the DM's risk-aversion constant for the  $j$ th threat factor in the  $i$ th environment.

The DM's risk-aversion constant ( $r$ ) is assumed to be greater than zero, representing aversion toward risk. SAM does not consider  $r=0$ , which represents risk neutrality, or  $r<0$ , which represents preference toward risk, a behavior which is not evident in the world of business [20]. In addition:

$$\sum_{i=1}^3 W_{u_i} = 1, \quad (9)$$

$$\sum_{i=1}^3 W_{t_i} = 1, \quad (10)$$

$$\sum_{j=1}^{N_{u_i}} \hat{F}_{u_{ij}} = 1, \quad (11)$$

$$\sum_{j=1}^{N_{t_i}} \hat{F}_{t_{ij}} = 1, \quad (12)$$

$$0 \leq p_{u_{ij}}^m \leq 1, \quad (13)$$

$$0 \leq p_{t_{ij}}^m \leq 1. \quad (14)$$

## A PRACTICAL APPLICATION

This example presents, in condensed form, a real-life problem. The name of the company has been changed to protect its identity. The study is centered on The City Hospital (TCH), a leading health care provider associated with the medical school of a university. The facility is involved in research and education in various facets of the health care profession. Like many other hospitals, TCH is faced with several challenges, not the least of which are financial in nature. The state legislature has eliminated much of its funding to the university resulting in a \$10 million operating deficit for the hospital. Furthermore, the business community is seeking a reduction