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Euclid: Strategic Alternative Assessment Matrix

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ABSTRACT

The vast amount of information that must be considered to solve inherently ill-structured and complex strategic problems creates a need for tools to help decision makers (DMs) recognize the complexity of this process and develop a rational model for strategy evaluation. Over the last several decades, a philosophy and a body of intuitive and analytical methods have been developed to assist DMs in the evaluation of strategic alternatives. However, the intuitive methods lack a structured framework for the systematic evaluation of strategic alternatives while the analytical methods are not intended to capture intuitive preferences. *Euclid* is a simple and yet sophisticated multiobjective value analysis model that attempts to uncover some of the complexities inherent in the evaluation of strategic alternatives. The proposed model uses a series of intuitive and analytical methods including environmental scanning, the analytic hierarchy process (AHP), subjective probabilities, and the theory of displaced ideal, to plot strategic alternatives on a matrix based on their Euclidean distance from the ideal alternative. *Euclid* is further compared to the quantitative strategic planning matrix (QSPM) in a real world application. The information provided by the users shows that *Euclid* can significantly enhance decision quality and the DM's confidence. *Euclid* is not intended to replace the DMs, rather, it provides a systematic approach to support, supplement, and ensure the internal consistency of their judgments through a series of logically sound techniques. Copyright © 2003 John Wiley & Sons, Ltd.

KEY WORDS: strategic decision making; environmental scanning; analytic hierarchy process; subjective probabilities; theory of displaced ideal

1. INTRODUCTION

Complexity forms the essence of strategic decision making. The process of strategic decision making involves so many dimensions that the solutions and simplifications in one dimension cause problems and complexities in another. Strategic decision making is by its nature ill-structured, complex and yet very important for the success and survival of an organization (Schwenk, 1988). It is often difficult to cope with large volumes of potentially important information during strategy evaluation. Strategic decision making tends to be characterized by high levels of complexity, putting enormous cognitive demands on decision makers (DMs). The vast amount of information that must be considered for solving these inherently ill-structured strategic problems creates a need for tools to help DMs recognize the complexity of this process and develop a rational model for strategy evaluation (Fahey *et al*., 1981; Klein and Newman, 1980; Weigelt and Macmillan, 1988). Hofer and Schendel (1978) note that most DMs perform far better when they separate this process into distinct steps, address each step separately, and then combine the results at the end.

Over the last several decades, a philosophy and a body of intuitive and analytical models have been developed to assist DMs in the evaluation of strategic alternatives. Some of the intuitive models include dialectic policy analysis (Mitroff, 1982); vulnerability analysis (Hurd, 1979); corporate simulation models (Ginter and Rucks, 1984; Naylor and Schauland, 1976; Nees, 1983); portfolio models (Cardoza and Wind, 1985; Naylor, 1982); dialectical inquiry, devil's advocacy, and the consensus approach (Schweiger *et al*., 1986, 1989: Schweiger and Sandberg, 1989). Although these techniques have a theoretical appeal, their application seems to be *ad hoc*, and they lack a structured framework for the systematic evaluation of strategic alternatives. Some of the analytical models include strategic program evaluation (Grant and King, 1982a; King, 1980), quantitative strategic planning matrix (David, 1985, 1986, 1993), Electre

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II (Godet, 1987), the McKinsey matrix (Hill and Jones, 1989), competitive strength assessment (Thompson and Strickland, 1998), the scenario-strategy matrix (Naylor, 1983), and decision situation outcomes evaluation (Radford, 1980). These techniques have made contributions to the strategy evaluation process, but are not intended to capture intuitive preferences or to model environmental processes (Edwards *et al*., 1988). Other more recently developed methods blend intuitive and analytical approaches (Tavana and Banerjee, 1995). However, these methods lack simplicity and are primarily used by highly trained managers. Simplicity helps the DM implement the tools that have been developed and communicate the results of this utilization (Edwards *et al*., 1988).

Schoemaker and Russo (1993) describe four general approaches to decision making ranging from intuitive to highly analytical. These methods include intuitive judgments, rules and shortcuts, importance weighting, and value analysis. They argue that analytical methods such as importance weighting and value analysis are more complex but also more accurate than the intuitive approaches (Schoemaker and Russo, 1993). *Euclid* is a simple and yet sophisticated multiobjective value analysis model that attempts to uncover some of the complexities inherent in the evaluation. The proposed approach uses a series of intuitive and analytical methods to plot strategic alternatives on a matrix based on their Euclidean distance from the ideal alternative. Using the theory of displaced ideal to grasp the extent of the emerging conflict between means and ends, the DM explores the limits attainable with each environmental benefit and risk. The highest achievable scores with all currently considered benefits and risks form a composite, an 'ideal alternative' (Zeleny, 1982).

Euclid captures the DM's beliefs through a series of sequential, objective, and structured processes. Organizational members demand a sound rationale for strategic decisions. Unless that rationale is seen to be at least somewhat structured and objective, the commitment required may not exist or be sustained (Moore, 1995). An objective and structured strategic decision making procedure can be very useful in clarifying the elements of a decision and arriving at the best decision (Kirkwood, 1997). Strategic decision making can be improved using a formal decision making process (Ansoff, 1980; Camillus, 1975). Quantitative data often clarifies the elements of strategic decisions, and it forces DMs to be explicit about their reasoning. This improves decision making, and it also aids communication about the basis for a decision (Kirkwood, 1997).

Euclid promotes comprehensive scanning of the environment by decomposing the environmental forces into internal, transactional, and contextual benefits and risks as suggested by many researchers (Daft *et al*., 1988; Grant and King, 1982a,b; Rhyne, 1985; Schmid, 1986). The open system approach to organizations recognizes that there is an identifiable, if semi-permeable, layer between the organization and its environment. It is vital to view the internal context of the organizations as being embedded in its external environment. The context of an organization (both internal and external) refers generally to the environment from which it has emerged and in which it exists and can reasonably be seen as the fundamental base from which the success and failure of strategy can be understood.

Euclid uses intuitive and analytical methods such as environmental scanning, the analytic hierarchy process (AHP), subjective probabilities, and the theory of displaced ideal to enhance decision quality and the DM's confidence in evaluating a set of strategic alternatives. The next sections present a step-by-step explanation of the procedure, the model, a practical application, managerial implications, and conclusion.

2. THE PROCEDURE

Euclid uses a six-step procedure to systematically evaluate potential strategies by plotting them in a four-quadrant matrix based on their Euclidean distance from the ideal alternative. The six steps used in *Euclid* are:

(i) Generate strategic alternatives;
(ii) Identify the relevant benefits and risks and group them into internal, transactional, and contextual sets of environmental factors;
(iii) Define environmental weights and the importance weight of each benefit and risk;
(iv) Develop subjective probabilities for each alternative;
(v) Identify the ideal probabilities and calculate the total Euclidean distance of each strategic alternative; and
(vi) Select the most attractive alternative using visual and numerical information.

Each of these steps is described below.

(i) *Generate strategic alternatives:* Alternatives are the set of potential means by which the previously identified objectives may be attained. There must be a minimum of two mutually exclusive alternatives in the set to permit a choice to be made (Zeleny, 1982). In well-structured problems, alternative generation may be relatively routine. However, in most strategic problems this task is anything but routine because this type of problem is normally ill-structured. Alternatives can be generated using various brainstorming and intuitive methods. Keller and Ho (1988) discuss several alternative generation approaches that could be used in a formal strategic decision making model.

(ii) Identify the relevant benefits and risks and group them into internal, transactional, and contextual sets of environmental factors: Next, environmental scanning is used to assemble and analyse potential benefits and risks within the internal, transactional, and contextual environments. The internal environment consists of benefits and risks within the functional areas of a firm such as finance, sales, personnel, and manufacturing. The transactional environment includes factors that directly affect and are affected by an organization's major operations. Some of these factors include benefits and risks associated with competitors, customers, creditors, suppliers, labor unions, trade associations, and special interest groups. The contextual environment includes mainly uncontrollable factors such as socio-cultural, technological, political, and legal benefits and risks. When more than one DM is involved in the decision process, all the DMs participate collectively in identifying the benefits and risks. Aguilar (1967) presents a detailed discussion of environmental factors that could be considered during the strategic decision making process.

(iii) *Define environmental weights and the importance weight of each benefit and risk:* Multi-criteria decision making (MCDM) techniques require the determination of a set of weights that reflect the relative importance of various competing objectives. Several approaches such as point allocation, paired comparisons, trade-off analysis and regression estimates could be used to specify these weights (Kleindorfer *et al.*, 1993). *Euclid* utilizes AHP developed by Saaty (1977, 1980, 1990a) to estimate environmental weights for benefits (W_{b_t}) and risks (W_{r_i}). AHP is also used to estimate the importance weight of each benefit ($F_{b_{ij}}$) and risk ($F_{r_{ij}}$). The process is simplified by confining the estimates to a series of pairwise comparisons. The measure of inconsistency provided by AHP allows for the examination of inconsistent priorities.

Shoemaker and Waid (1978) have compared AHP with three commonly used multicriteria decision making techniques including multiple regression, the multi-attribute utility approach of Keeney and Raiffa (1976) and simple direct assessment. These methods differ in several ways: (1) they require different types of judgments, (2) they require different response modes, and (3) they have different application domains. Shoemaker and Waid (1978) show that all four methods produce similar results, but each has advantages over the others. AHP does not require consistency among preferences, while the construction of a utility function by the multi-attribute utility approach requires a transitive preference relation. In addition, AHP provides more detailed information from its pairwise comparison process, and it is applicable in domains where non-measurable factors exist. For repetitious decision-making situations, the multi-attribute utility approach is more advantageous. However, in practice, utility functions change rapidly and need to be re-evaluated frequently. Thus, the multiple attribute utility approach does not do better operationally than AHP. AHP is also preferred to multiple regression and direct access for non-repetitive decision making situations because these situations do not allow an easy derivation of measurable factors. *Euclid* does not use AHP conventionally to determine the relative importance of each alternative in terms of the decision factors. Instead, probabilities of occurrence are used to capture the relative performance of each alternative. These probabilities are used to identify ideal probabilities and form the ideal alternative discussed later. AHP has been a very popular technique for determining weights in MCDM problems (Shim, 1989; Zahedi, 1986). The advantage of AHP is its capability to elicit judgments and scale them uniquely using a procedure that measures the consistency of these scale values (Saaty, 1989).

Euclid is a normative MCDM model with multiple factors representing different dimensions from which the alternatives are viewed. When the number of factors is large, typically more than a dozen, they may be arranged hierarchically (Saaty, 1980; Triantaphyllou, 2000; Triantaphyllou and Mann, 1995). *Euclid* assumes a hierarchical structure by initially classifying decision factors into opportunities and threats. Opportunities and threats are further classified into internal, transactional, and contextual categories. This hierarchical structure allows for a systematic grouping of decision factors in large problems. The classification of different factors is undoubtedly the most delicate part of the problem formulation (Bouyssou, 1990) because all different aspects of the problem must be represented while avoiding redundancies. Roy and Bouyssou (1987) have developed a series of operational tests that can be used to check the consistency of this classification.

There has been some criticism of AHP in the operations research literature. Harker and Vargas (1987) show that AHP does have an axiomatic foundation, the cardinal measurement of preferences is fully represented by the eigenvector method, and the principles of hierarchical composition and rank reversal are valid. On the other hand, Dyer (1990a) has questioned the theoretical basis underlying AHP and argues that it can lead to preference reversals based on the alternative set being analysed. In response, Saaty (1990b) explains how rank reversal is a positive feature when new reference points are introduced. In *Euclid*, the geometric aggregation rule is used to avoid the controversies associated with rank reversal (Dyer, 1990a,b; Harker and Vargas, 1990; Saaty, 1990b).

(iv) *Develop subjective probabilities for each alternative:* The probability of occurrence of each benefit ($p^m_{b_{ij}}$) and risk ($p^m_{r_{ij}}$) for each alternative is estimated. Subjective probabilities are commonly used in strategic decision making because they require no historical data (observation of regularly occurring events by their long-run frequencies) (De Kluyver and Moskowitz, 1984; Schoemaker, 1993; Schoemaker and Russo, 1993; Vickers, 1992; Weigelt and Macmillan, 1988). Subjective probabilities can be measured by asking a DM for the odds on an event. If the DMs are familiar with probability concepts, they can be asked directly for the required probability. If not, some sort of measuring instrument is required. Some researchers suggest using verbal phrases such as ''likely,'' ''possible,'' ''quite certain,'' etc., to elicit the required information and then converting them into numeric probabilities (Brun and Teigen, 1988; Budescu and Wallsten, 1985; Tavana *et al*., 1997). Other commonly used approaches include reasoning (Koriat *et al*., 1980), scenario construction (Schoemaker, 1993) and cross-impact analysis (Stover and Gordon, 1978). In this study, the verbal probabilistic phrases in Table I were used to elicit numeric probabilities as suggested by Tavana *et al*., (1997). Alternatively, the DM may use numeric probabilities instead of the probabilistic phrases. Merkhofer (1987) and Spetzler and Stael von Holstein (1975) review some probability elicitation procedures that are used in practice.

The probabilities associated with the decision factors are assumed to be binomial. Binomial probabilities are commonly used in strategic decision making so that the decision maker can simplify the problem by analysing possible outcomes as either occurring or not occurring. For example, Schoemaker (1993) assigns binomial probabilities to factors such as ''Dow Jones Industrial Average falling below 1500 mark by 1990'' or ''Election of a Democrat as US president by 1990.'' Vickers (1992) also assigns binomial probabilities to similar factors such as ''Japanese car manufacturers gain at least 30% of the European market share'' and ''The incorporation of East Europe into Europe by 1993'' in order to examine the future of European automobile industry. The main motivation for using the binomial probabilities is to reduce the complexity of the model and allow DMs use event-driven factors.

(v) *Identify the ideal probabilities and calculate the total Euclidean distance of each strategic alternative: Euclid* is a weighted-sum, multicriteria decision model (Triantaphyllou, 2000). Many weighted-sum models such as strategic program evaluation (Grant and King, 1982a,b; King, 1980) and QSPM (David 1985, 1986, 1993) have been

Table I. Verbal probabilistic expressions and perceived probability estimates

Verbal Expression	Probability
Impossible	0.00
Small possibility	0.10
Small chance	0.20
Somewhat doubtful	0.30
Possible	0.40
Toss-up	0.50
Somewhat likely	0.60
Likely	0.70
Very likely	0.80
Quite certain	0.90
Certain	1.00

developed to help DMs deal with the strategy evaluation process. The weighted-sum scores in *Euclid* are used to compare potential alternatives among themselves and with the ideal alternative. The concept of ideal alternative, an unattainable idea, serving as a norm or rationale facilitating human choice problem is not new. See for example the stimulating work of Schelling (1960), introducing the idea. Subsequently, Festinger (1964) showed that an external, generally non-accessible alternative assumes the important role of a point of reference against which choices are measured. Zeleny (1974, 1982) demonstrated how the highest achievable scores on all currently considered decision criteria form this composite ideal alternative. As all alternatives are compared, those closer to the ideal are preferred to those farther away. Zeleny (1982, p. 144) shows that the Euclidean measure can be used as a proxy measure of distance. Using the Euclidean measure suggested by Zeleny (1982), *Euclid* synthesizes the results by taking the square root of the sum of the squares of the benefit and risk ratings.

As suggested by Zelany (1982), the ideal probability of each benefit and risk is identified. The ideal probability for a benefit ($P^*_{b_{ij}}$) is the highest probability among the set of subjective probabilities developed in the previous step while the ideal probability for a risk ($P^*_{r_{ij}}$) is the lowest probability among the set. As shown in Equations (1) and (2), two composite scores called the total Euclidean distance from the ideal benefit (B^m) and total Euclidean distance from the ideal risk (R^m) are developed for each strategic alternative. First, the Euclidean distance of each probability from its respective ideal probability is calculated. This Euclidean distance is the ideal probability minus the probability squared. Next, the composite scores which are the sum of the Euclidean distances for each benefit and risk times its importance weight and the weight of the environments are determined.

(vi) *Select the most attractive alternative using visual and numerical information:* The strategic alternatives are next plotted on a matrix similar to Figure 1 along with the mean Euclidean distance of benefits ($\bar{B}$) and risks ($\bar{R}$). The horizontal dimension (*x*-axis) indicates B^m while the vertical dimension (*y*-axis) shows R^m. With the ideal alternative ($B^* = 0$), ($R^* = 0$) as the origin, the mean Euclidean distance of benefits and risks divide the matrix into four quadrants: *Exploitation*, *Challenge*, *Discretion*, and *Desperation* Zones.

Exploitation Zone: In this quadrant, benefits are strong ($B^m \leqslant \bar{B}$) and risks are weak ($R^m \leqslant \bar{R}$) because the strategy is close to both the ideal benefit and risk points. This area represents the greatest possible advantage for a firm. Strategies falling into this zone should be considered seriously by the firm.

Challenge Zone: In this quadrant, benefits are strong ($B^m \leqslant \bar{B}$) and risks are strong ($R^m > \bar{R}$) because the strategy is closer to the ideal benefit point than the ideal risk point. This zone requires full use of the firm's abilities and resources.

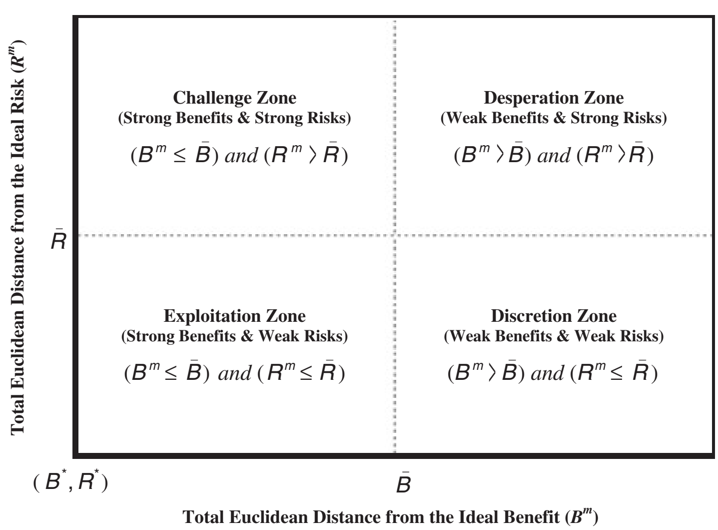

Figure 1. The four quadrants and their characteristics.

Discretion Zone: In this quadrant, benefits are weak ($B^m > \bar{B}$) and risks are weak ($R^m \leqslant \bar{R}$) since the strategy is closer to the ideal risk than the ideal benefit. This zone represents the area where the firm has freedom or power to act or judge on its own.

Desperation Zone: In this quadrant, benefits are weak ($B^m > \bar{B}$) and risks are strong ($R^m > \bar{R}$) because the strategy is far from both the ideal benefit and risk points. Strategies falling into this zone should be undertaken as a last resort.

The value determination procedure has been specified so that an alternative that has the most preferred score on both dimensions will have a value of zero for (B^m) and (R^m). Similarly, an alternative that has the least preferred score on these two dimensions will have a value of 1 for (B^m) and (R^m). Typically, there will not be any actual alternatives that are this good or bad, but the value number for the actual alternatives can be interpreted by comparing these actual alternatives with the ideal alternative having values of zero for (B^m) and (R^m). The value number for a particular alternative gives the proportion of the distance, in a value sense, that an alternative is from the ideal alternative. In cases where more than one strategy falls into one of these quadrants, the one with the lowest overall Euclidean distance (D^m) is the preferred strategy.

Consider hypothetical alternative A with $B^A = 0.40$ and $R^A = 0.30$. No specific meaning can be given to value numbers without considering the ranges of the evaluation measures that are being used ($0 \leqslant B^m \leqslant 1$ and $0 \leqslant R^m \leqslant 1$). In this context, the value of 0.40 means that alternative A is 40% away from the ideal benefit and 60% away from the alternative with the worst possible benefit. Similarly, the value of 0.30 means that alternative A is 30% away from the ideal risk and 70% away from the alternative with the worst possible risk. Equation (3) calculates the overall Euclidean distance of alternative A from the ideal alternative ($D^A = \sqrt{(0.40)^2 + (0.30)^2} = 0.50$). The overall distance of alternative A from the worst possible alternative is ($\sqrt{2} - 0.50$) which is 0.92. This means, alternative A is relatively closer to the ideal alternative than the worst possible alternative.

Once the model is developed, sensitivity analyses can be performed to determine the impact on the ranking of alternatives for changes in various model assumptions. Some sensitivity analyses that are usually of interest are on the weights and probabilities of occurrence. The weights representing the relative importance of the environments, benefits, and risks are occasionally a point for discussion among the various DMs. In addition, probabilities of occurrence which reflect the degree of belief that an uncertain event will occur are sometimes a matter of contention.

3. THE MODEL

To formulate the model algebraically, let us assume:

B^m = Total Euclidean distance from the ideal benefit for the mth strategic alternative; ($m = 1,2, \ldots, M$)
R^m = Total Euclidean distance from the ideal risk for the mth strategic alternative; ($m = 1,2, \ldots, M$)
D^m = Overall Euclidean distance of the mth strategic alternative; ($m = 1,2, \ldots, M$)
$\bar{B}$ = Mean Euclidean distance of the benefits
$\bar{R}$ = Mean Euclidean distance of the risks
W_{b_i} = The ith environment weight for benefits; ($i = 1,2$, and 3)
W_{r_i} = The ith environment weight for risks; ($i = 1,2$, and 3)
$F_{b_{ij}}$ = The importance weight for the jth benefit in the ith environment; ($j = 1,2, \ldots, J_{b_i}$; and $i = 1,2$, and 3)
$F_{r_{ij}}$ = The importance weight for the jth risk in the ith environment; ($j = 1,2, \ldots, J_{r_i}$; *and* $i = 1, 2$, and 3)
$P^m_{b_{ij}}$ = Probability of occurrence of the jth benefit in the ith environment given the choice of mth strategic alternative; ($m = 1,2, \ldots, M$; $j = 1,2, \ldots, J_{b_i}$; and $i = 1,2$, and 3)
$P^m_{r_{ij}}$ = Probability of occurrence of the jth risk in the ith environment given the choice of mth strategic alternative; ($m = 1, 2, \ldots, M$; $j = 1, 2, \ldots, J_{r_i}$; and $i = 1, 2$, and 3)
$P^*_{b_{ij}}$ = The ideal probability of occurrence of the jth benefit in the ith environment; ($j = 1, 2, \ldots, J_{b_i}$; and $i = 1, 2$, and 3)
$P^*_{r_{ij}}$ = The ideal probability of occurrence of the jth risk in the ith environment; ($j = 1, 2, ..., J_{r_i}$; and $i = 1, 2$, and 3)
N_{b_i} = Number of benefits in the ith environment ($i = 1, 2$, and 3)
N_{r_i} = Number of risks in the ith environment ($i = 1, 2$, and 3)

Assuming *that* $i = 1$–3 represent the internal, transactional, and contextual environments.

$$B^m = \sum_{i=1}^{3} W_{b_i} \left(\sum_{j=1}^{J_{b_i}} F_{b_{ij}} \left[\left(P^*_{b_{ij}} - P^m_{b_{ij}} \right)^2 \right] \right) \quad (1)$$

$$R^m = \sum_{i=1}^{3} W_{r_i} \left(\sum_{j=1}^{J_{r_i}} F_{r_{ij}} \left[\left(P^*_{r_{ij}} - P^m_{r_{ij}} \right)^2 \right] \right) \quad (2)$$

$$D^m = \sqrt{B^{m^2} + R^{m^2}} \quad (3)$$

$$\bar{B} = \sum_{m=1}^{M} B^m / M \quad (4)$$

$$\bar{R} = \sum_{m=1}^{M} R^m / M \quad (5)$$

where

$$P^*_{b_{ij}} = \underset{m}{\text{Max}}\, P^m_{b_{ij}}$$

$$P^*_{r_{ij}} = \underset{m}{\text{Min}}\, P^m_{r_{ij}}$$

$$\sum_{i=1}^{3} W_{b_i} = 1$$

$$\sum_{i=1}^{3} W_{r_i} = 1$$

$$\sum_{j=1}^{J_{b_i}} F_{b_{ij}} = 1$$

$$\sum_{j=1}^{J_{r_i}} F_{r_{ij}} = 1$$

$$0 \leqslant P^m_{b_{ij}} \leqslant 1$$

$$0 \leqslant P^m_{r_{ij}} \leqslant 1$$

4. A PRACTICAL APPLICATION

From its inception in the early 1950s as a designer and manufacturer of custom machinery, Semicon† has become one of the leading US suppliers of assembly equipment to the international semiconductor industry. Over the past 15 years the semiconductor industry has undergone major structural changes that have had profound consequences for Semicon. In the mid 1970s US producers of semiconductors controlled about 65% of the world market while Japan controlled only 25%. Today the positions of both countries' companies have almost reversed. Semicon's management has decided to expand its presence in Japan from a sales and service office located in Tokyo to one of the four alternatives listed below (step (i)):

Alternative A—increase sales presence in Japan: Currently, Semicon has a sales and service office in Tokyo with eight salespeople covering the major semiconductor houses, most of which are located in Tokyo. While their presence in front of customers' purchasing and corporate personnel has been acceptable, it is the process engineers and manufacturing people in the outlying factories who form the basic support for any equipment acquisitions. These factories are usually located in other parts of Japan, and the management feels that their presence needs to be increased at these locations. The challenge would be in hiring top quality Japanese personnel to fill these positions. It is still difficult for an American company to recruit top Japanese university graduates and industry people. Most of them either work for, or want to work for, the top Japanese companies.

Alternative B—design a machine especially for Japanese customers: One reason for the small market share of Semicon in Japan is the lack of appropriate machinery. A development project could be undertaken to design and manufacture a machine specifically for the Japanese market. A new machine designed correctly would compete successfully with Oshinawa† in the most important areas in Japan. Consequently, R&D expenses would need to be increased beyond their already historically high level, or other projects critical to supporting core markets would need to be scaled back. This would be a major project in terms of engineering manpower as well as cost.

Alternative C—jointly manufacture existing equipment in Japan: Japanese customers' confidence in a supplier is directly proportional to the supplier's presence in Japan. The same personnel problems as those discussed in increasing the sales force would be encountered, only on a much larger scale. A joint venture with a Japanese manufacturer of precision equipment could eliminate the

†The name of the company has been changed to protect its anonymity.

personnel issues, and would allow a much faster and less costly implementation curve. In return for sharing the benefits of this enterprise with another company, Semicon would have a good chance of putting pressure on Oshinawa in its core market, something the company has been unable to do. Putting Oshinawa in a defensive position would cause it to allocate more of its resources to defend its base and would leave Semicon a larger share of the non-Japan market. In addition, the increase Oshinawa would experience in its operating costs would put upward pressure on its prices and would make Semicon even more competitive. Finally, by manufacturing and selling in Japan, most of the risk from exchange rate fluctuations would be eliminated.

Alternative D—Drop prices: Lower base prices coupled with the weaker dollar would allow Japanese customers to view Semicon equipment as superior in price/performance analyses. If the Japanese economy does not improve soon, putting such pressure on in the short term may have enough of a negative impact on Oshinawa to cause them serious problems for several years. In the meantime, Semicon could be making inroads in Japan. The obvious concern here is that such a price action will be a drag on margins, and may set pricing precedents that will be difficult to change in the future. Also, the Japanese may not desert Oshinawa solely because of lower prices unless Semicon's price/performance ratio is at least an order of magnitude better.

In step (ii), the DM identified the benefits and risks for the internal, transactional, and contextual environments. They are presented in Table II.

4.1. Internal benefits

ABP—Automation of business processes: In order to become more competitive on a cost structure basis, it is imperative that Semicon upgrade and consolidate their order processing and manufacturing systems.

ITK—increase technical knowledge base: An increased presence in Japan, in any of the forms discussed above, would provide a better understanding of Japanese customer needs. By doing a better job of designing solutions into their machines, Semicon would be providing unsurpassed customer service while gaining valuable technical knowledge. Increased technical knowledge for Semicon could translate into greater market share and margins.

RQI—Reaching $\geqslant$85% quality index level in factory: Japanese customer requirements could drive Semicon to greater levels of quality in their equipment. One good measure of quality shipped out the door is the quality index level used by Semicon. Although the current 75% level is a big improvement from past performance, higher levels would be needed to compete directly with Oshinawa in their home market. It is a customer requirement that a machine be uncrated and run ''out of the box'' so that machine utilization is maximized.

OTD—Reaching actual delivery against commitment of $\pm$3 days: Another area Semicon would need to improve in order to gain market share in Japan is meeting delivery commitments. Japanese markets are volatile, and it is difficult to forecast specific product mixes and shipment quantities for a particular period of time with a high degree of accuracy. However, to compete in Japan, Semicon would need to assure that delivery occurs within 3 days of the committed delivery.

IES—Improve employee skills: All of the previously stated objectives require a concerted effort to increase the skill levels of Semicon's employees. Engineering, manufacturing, marketing, and sales people will not only need to know how to improve the company's performance, but will also need a thorough understanding of the Japanese environment. Japan has economic, cultural, and social dimensions that are diverse and must be addressed if Semicon is to be successful.

4.2. Transactional benefits

ICR—Improve company reputation: If Semicon can compete successfully in Japan, it will have accomplished something that very few non-Japanese companies have done. Success is really not an option for Semicon. Success in the Japanese markets would bring a special status that, while intangible, would be very valuable in other markets. Semicon would no longer suffer the perception problems it now encounters with some of its other customers who use Japanese equipment. Neutralizing some of these quality and customer service issues could translate directly into increased sales.

ICS—Improve competitive cost structure: This is an important competitive issue. Re-engineering processes and systems in the company will have a positive effect on costs. Manufacturing costs would be most directly affected, while R&D costs would be more dependent upon the marketing

Table II. Environmental benefits and risks

Benefits	
Internal environment	
ABP	Automation of business processes
ITK	Increase technical knowledge base
RQI	Reaching 85% quality index level in factory
OTD	Reaching actual delivery against commitment of $\pm$ 3 days
IES	Improve employee skills
Transactional environment	
ICR	Improve company reputation
ICS	Improve competitive cost structure
PCB	Protect core business
KJC	Key Japanese components more available to Semicon
Contextual environment	
SGL	Special government legislation to help semiconductor trade
FER	Falling exchange rate
JER	Japanese economic rebound within next 2–3 years
Risks	
Internal environment	
IRD	Increase In R&D expenses
LPM	Lower prices and margins
RTW	Resistance to increased workloads required to compete
HET	Higher employee training and educational expenses
Transactional environment	
JPI	Japanese personnel hiring and training issues
HCB	High cost of doing business in Japan
CCS	Competitor's counter strategies could cause pain
LOF	Loss of focus on core business
Contextual environment	
BTE	High barriers to entry
JCD	Japanese culture is significantly different than US
CJR	Continued Japan recession would hurt prospects
PTF	Possible trade friction between the US and Japan

decisions made by Semicon. Even so, there would be some benefit in this area just from being able to access the automated and integrated systems in other parts of the company. If Semicon can reduce its costs and approach Oshinawa's cost structure, price competitiveness would improve, especially in Japan.

PCB—Protect core business: A Semicon assault on the Japanese market, Oshinawa's core business, with high quality, price competitive products, would require Oshinawa to enact defensive countermeasures. These measures require Oshinawa to make significant expenditures and to reallocate some of their resources, particularly in sales, engineering, and marketing. If Oshinawa tries to defend their positions in both the US and Japan markets simultaneously, their current cost and resource problems would most likely be exacerbated further.

KJC—Key Japanese components more available to semicon: As Semicon increases its presence in Japan, it would not only learn more about its customers, but it would also have the ability to do business with leading Japanese vendors of key precision machine components. In some areas, the Japanese offer superior technology than that available in the US. Incorporating Japanese components in these instances would improve machine performance and reliability.

4.3. Contextual benefits

SGL—Special government legislation to help semiconductor trade: For the past decade, trade between the US and Japan has been a source of acrimony between both countries. The US claims that Japan's huge trade surplus is due, in large part, to non-tariff trade barriers that created virtually closed markets. Japan claims that the

US' problems are due mostly to its huge budget deficits that ultimately cause a reduction in competitiveness. However, the US has been able to get Japan to agree to specific targets for sales of US semiconductors in Japan. While the merits of this agreement could be debated in a larger, macro-economic context, further developments of this nature would be favorable to Semicon. Just as the US equipment industry followed the US semiconductor industry in lost market share, it is reasonable to expect that the reverse could occur.

FER—Falling exchange rate: Whether the dollar will continue to weaken against the yen remains to be seen. A weaker dollar allows the Japanese to spend fewer yen than they would otherwise have used to purchase Semicon's equipment. This would allow Semicon to reduce prices and put further pressure on Oshinawa.

JER—Japanese economic rebound within next 2–3 years: Along with the current competitive disadvantages Semicon faces in Japan, the weak Japanese economy has also had negative impact on Semicon's business prospects. The management believes that this should change radically in the near future. Japanese companies are moving towards restructuring through layoffs, early retirement, etc. In addition, capital spending, which has also been curtailed for replacement equipment, should rise as it becomes impossible to produce new, complex semiconductors on older machines.

4.4. Internal risks

IRD—Increase in R&D expenses: Management believes it is very important for Semicon to continue their leadership in the US market. This is likely to require an increase in R&D spending.

LPM—Lower prices and margins: In Japan, prices for the same type of equipment as that sold in the rest of the world tend to be lower. This is due to the relationship Japanese customers have with their vendors, and manufacturers have with their subcontractors. In return for getting a lower price, a vendor is assured of a long-term relationship with a customer. A major foray into Japan means that Semicon will see its current margins erode to some extent. If costs are kept under tight control, then a 3–5% reduction in gross margin can be expected, otherwise a 5–9% reduction is possible. This is a significant risk because healthy margins are required to fund the development of technologically sophisticated products.

RTW—Resistance to increased workloads required to compete: A major increase in activity across most of the company will be required to successfully expand Semicon's market share in Japan. Management will be challenged to motivate its employees to not only accept this large job, but also to perform at the high level required for success.

HET—Higher employee training and educational expenses: It is obvious that increasing employee skills does not come without a cost. Although increasing the skills needed to succeed in Japan is essential, the costs will have to be considered when evaluating Semicon's cost structure versus Oshinawa's. Again, some trade-offs may be required.

4.5. Transactional risks

JPI—Japanese personnel hiring and training issues: Japanese personnel would be needed to manage and run some of Semicon's operations in Japan. The goal of any Japanese joining the labor force is to join a top Japanese firm. This is not just an economic desire but also one of great pride. Consequently, top Japanese companies have access to the best and brightest people in the labor force. It would be very difficult for Semicon to recruit and hire good Japanese managers and workers.

HCB—High cost of doing business in Japan: It is well known that Tokyo, and to a lesser extent the rest of Japan, is one of the most expensive places to live and work in the world. The salaries of Japanese workers would not be prohibitive. However, the cost of expanding in Japan would be felt primarily in additional rents and leases, and in any costs incurred by US expatriates living in Japan.

CCS—Competitor's counter strategies could cause pain: Semicon's management believes that there is a possibility that Oshinawa and its workers could make the sacrifices necessary to keep costs in line as they confront the need to cut their prices. Oshinawa might even cut its prices to the point where Semicon would find its margins eroding to an unacceptable degree. Any number of other actions Oshinawa could take including enhanced products, more sales coverage or more attractive terms would hurt Semicon's bottom line.

LOF—Loss of focus on core business: In pursuing the Japanese market, Semicon would need to be very careful not to neglect its US market. Even though succeeding in Japan is essential to long term growth, losing dominance in the US market could have harmful consequences.

4.6. Contextual risks

BTE—High barriers to entry: Much of the trade friction that Japan encounters with other countries is a consequence of its non-tariff barriers. For example, the separate standards and regulations that foreign companies must meet for access to Japan's consumers are more onerous than those faced by Japanese companies. Another example is that success, in many cases, requires a working knowledge of, and access to, Japan's Byzantine distribution networks. In Semicon's case, equipment evaluation requirements that are longer and more stringent than those that are required of Oshinawa could be a problem. These barriers are certainly areas of risk that will add cost to implementing the strategy.

JCD—Japanese culture is significantly different than US: One problem that will need to be addressed in a major expansion effort in Japan is how to run an operation, negotiate contracts, and deal with employees playing under rules that are often unfamiliar. An important part of Japanese business culture is that a solid relationship and local presence must be established before any outside vendor can win large orders.

CJR—Continued Japan recession would hurt prospects: A return on the large investment in Japan will not be possible until Japan's economy begins to recover. The key is to time the implementation in Japan to occur as closely as possible to the end of the recession. This may be difficult to time exactly, but a gross error could seriously harm the company.

PTF—Possible trade friction between the US and Japan: There is always the possibility that a small trade skirmish could escalate into a trade war. This is not unlikely given the often contentious relationship between the two countries. If this occurs, retaliatory measures by the Japanese could make Semicon equipment cost prohibitive in Japan. Obviously, this is detrimental to achieving the strategic objectives specified above.

In step (iii), the DM estimated the relative importance of the internal, transactional and contextual environments through a series of pairwise comparisons required by AHP. Using Expert Choice (1990), an AHP-based software, the DM provided the pairwise comparisons presented in the environmental comparisons section of Tables III and IV. Expert Choice synthesized these judgments and provided the DM with the relative weights and the inconsistency ratios that are also presented in Tables III and IV. The DM was asked to re-evaluate his judgments if the inconsistency ratio was greater than 10%. It is clear that for the Benefits, the internal environment, with a weight of 0.659, outweighs other environments; for the Risks, the transactional environment is most important (0.696).

Expert Choice is used again by the DM in step iv to evaluate all the sets of environmental benefits and risks. For example, 10 pairwise comparisons were made between the internal benefits (ABP, ITK, RQI, OTD and IES) presented in Table III. Expert Choice used these judgments to estimate the relative weight associated with each internal benefit. If the inconsistency ratio was greater than 10%, the DM was asked to reconsider their judgments in the pairwise comparison matrix. One pairwise comparison matrix is needed for each set of benefits and risks in the internal, transactional and contextual environments. Therefore, the process of entering the judgments was repeated by the DM six times. All mathematical manipulations were performed by Expert Choice. The pairwise comparisons and weights for benefits are given in Table III and for the risks in Table IV.

Step (v) requires the DM to estimate the probability of occurrence for each benefit and risk under each potential alternative. These probabilities represent numerically the expectation of a factor's occurring. Using the verbal probability scale in Table I, the DM estimated the occurrence probabilities presented in Table V for all the benefits and risks associated with each alternative. For example, the DM estimated a 90% chance of reaching 85% quality index level (RQI) if a new machine is designed (Alternative B). However, the DM expects only 20% chance of achieving this target if prices are dropped (Alternative D).

In step (vi), the ideal probabilities presented in Table V were identified for each benefit and risk from the subjective probabilities within the table. For example, the ideal probability for RQI benefit (reaching 85% quality index level in factory) is 90% because it is the best (highest) among the set (70%, 90%, 20%, and 20%). However, the ideal probability for LPM risk (lower prices and margins) is 20% since it is the best (lowest) among the set (20%, 50%, 70%, and 60%).

The last step (step (vii)) is to calculate the total Euclidean distance of each strategic alternative from the ideal benefit and the ideal risk. The spreadsheet in Table VI was used to perform the operations specified in equations (1) and (2).

Table III. Pairwise comparison matrices (benefits)

Environmental comparisons
Inconsistency ratio = 0.030

	Internal	Transactional	Contextual	Relative weight
Internal	1	3	7	0.659
Transactional	1/3	1	4	0.263
Contextual	1/7	$\frac{1}{4}$	1	0.078

Internal factors
Inconsistency ratio = 0.051

	ABP	ITK	RQI	OTD	IES	Relative weight
ABP	1	1/5	1/9	1/7	1/5	0.033
ITK	5	1	1/5	1/4	1/3	0.088
RQI	9	5	1	2	4	0.452
OTD	7	4	$\frac{1}{2}$	1	2	0.267
IES	5	3	$\frac{1}{4}$	1/2	1	0.160

Transactional factors
Inconsistency ratio = 0.053

	ICR	ICS	PCB	KJC	Relative weight
ICR	1	2	4	9	0.501
ICS	1/2	1	3	7	0.310
PCB	1/4	1/3	1	6	0.149
KJC	1/9	1/7	1/6	1	0.040

Contextual factors
Inconsistency ratio = 0.070

	SGL	FER	JER	Relative weight
SGL	1	1/2	9	0.374
FER	2	1	8	0.571
JER	1/9	1/8	1	0.055

After calculating the total Euclidean distances of each alternative from the ideal alternative, the mean Euclidean distance of the benefits ($\bar{B} = 0.162$) and risks ($\bar{R} = 0.108$) were determined and plotted on a graph. The placement of the two means on the graph results in the formation of the four quadrants. Strategic choices with $B^m \leqslant 0.162$ and $R^m \leqslant 0.108$ fall in the *exploitation zone* while those with $B^m \leqslant 0.162$ and $R^m > 0.108$ fall in the *challenge zone*. Furthermore, strategic choices with $B^m > 0.162$ and $R^m \leqslant 0.108$ fall in the *discretion zone* and those with $B^m > 0.162$ and $R^m > 0.108$ fall in the *desperation zone*. As it is shown in Figure 2, alternative A ($B^A = 0.023$, $R^A = 0.027$) with strong benefits and weak risks is the most preferred alternative falling in the *exploitation zone*. Alternative C ($B^C = 0.267$, $R^C = 0.159$) with weak benefits and strong risks is the least preferred alternative falling in the *desperation zone*. Alternatives B and D fall in the *challenge zone* and *discretion zone* respectively.

5. FROM QSPM TO EUCLID

Solving MCDM problems is not searching for some kind of optimal solution, but rather helping DMs master the (often complex) data involved in their problem and advance toward a solution (Roy, 1990). As often happens in applied mathematics, the development of multicriteria models is dictated by real-life problems. It is therefore not surprising that methods have appeared in a rather diffuse way, without any clear general methodology or basic theory (Vincke, 1992). *Euclid* was developed after attempting to address a real-life strategic decision making problem using QSPM, a MCDM technique similar to the multiobjective value analysis proposed by Keeney (1992) and Kirkwood (1997). We found the results from QSPM to be unsatisfactory, then, our search for a better approach resulted in *Euclid*.

The author was hired as an external consultant to assist the strategic assessment committee of Semicon select one of the four previously defined

Table IV. Pairwise comparison matrices (risks)

Environmental comparisons					
Inconsistency ratio = 0.073					
	Internal	Transactional	Contextual		Relative weight
Internal	1	1/4	4		0.229
Transactional	4	1	7		0.696
Contextual	1/4	1/7	1		0.075
Internal factors					
Inconsistency ratio = 0.043					
	IRD	LPM	RTW	HET	Relative weight
IRD	1	1/2	2	7	0.278
LPM	2	1	5	8	0.529
RTW	1/2	1/5	1	5	0.149
HET	1/7	1/8	1/5	1	0.044
Transactional factors					
Inconsistency ratio = 0.002					
	JPI	HCB	CCS	LOF	Relative weight
JPI	1	1	1/8	1/5	0.066
HCB	1	1	1/8	1/5	0.066
CCS	8	8	1	2	0.557
LOF	5	5	1/2	1	0.311
Contextual factors					
Inconsistency ratio = 0.090					
	BTE	JCD	CJR	PTF	Relative weight
BTE	1	1	1/7	5	0.134
JCD	1	1	1/7	5	0.134
CJR	7	7	1	9	0.692
PTF	1/5	1/5	1/9	1	0.040

alternatives. The committee was appointed by the board of directors and comprised of twelve members, mostly senior managers with graduate education in business and engineering. The board invited the committee to work with the facilitator at a three-day decision conference outside the corporate settings and apart from daily interruptions and distractions. Decision conferencing is geared towards on-the-spot development of computer based decision models that incorporates the differing perspective of participants (McCartt and Rohrbaugh, 1989). The committee, with the author acting as facilitator and analyst, were expected to build a multicriteria decision model similar to QSPM and examine the implications of the model.

The assessment process began with a brainstorming session focusing on the question "what factors should be used in deciding whether to increase sales presence in Japan, design a machine especially for Japanese customers, jointly manufacture existing equipment in Japan, or drop prices?" Moore (1994) suggests several approaches which could be used to facilitate this process. The committee chose the flip-chart approach in which the participants listed their decision factors along with a brief justification on separate sheets of flip-chart paper. Once everyone completed this exercise, all flip-chart papers were posted for everyone to see. With the help of the facilitator, the committee discussed these factors and constructed a list on which they agreed. As suggested by Keeney (1992), the list was examined to assure the chosen factors were complete, operational, non-redundant, concise, measurable, understandable, and relevant.

As the conference continued, the committee was instructed to classify the decision factors into external opportunities/threats and internal strengths/weaknesses according to QSPM. During this classification process, participants were confused about the semi-controllable factors. The main difficulty was whether they should be included in the internal or external factors. The

Table V. Probabilities of occurrence and ideal probabilities

	Factors	Increase sales force (A)	Design new machine (B)	Joint venture to manufacture (C)	Drop prices (D)	Ideal probability
Benefits						
Internal	ABP	0.90	0.50	0.50	0.50	0.90
	ITK	0.50	0.70	0.70	0.20	0.70
	RQI	0.70	0.90	0.20	0.20	0.90
	OTD	0.90	0.70	0.20	0.20	0.90
	IES	0.60	0.70	0.40	0.20	0.70
Transactional	ICR	0.90	0.80	0.60	0.30	0.90
	ICS	0.60	0.40	0.40	0.50	0.60
	PCB	0.80	0.80	0.50	0.50	0.80
	KJC	0.20	0.60	0.90	0.10	0.90
Contextual	SGL	0.40	0.50	0.30	0.30	0.50
	FER	0.40	0.60	0.40	0.20	0.60
	JER	0.50	0.60	0.50	0.60	0.60
Risks						
Internal	IRD	0.40	0.90	0.40	0.10	0.10
	LPM	0.20	0.50	0.70	0.60	0.20
	RTW	0.40	0.60	0.60	0.30	0.30
	HET	0.60	0.70	0.40	0.30	0.30
Transactional	JPI	0.60	0.70	0.70	0.10	0.10
	HCB	0.30	0.30	0.90	0.10	0.10
	CCS	0.30	0.70	0.70	0.70	0.30
	LOF	0.50	0.70	0.50	0.40	0.40
Contextual	BTE	0.60	0.70	0.70	0.10	0.10
	JCD	0.30	0.30	0.90	0.10	0.10
	CJR	0.70	0.70	0.50	0.70	0.50
	PTF	0.50	0.70	0.50	0.40	0.40

facilitator suggested a two-level classification schema. The first level consisted of benefits (maximizing criteria) and risks (minimizing criteria). The second level consisted of internal (controllable), transactional (semi-controllable), and contextual (uncontrollable) factors. The committee agreed on the new hierarchy and six groups of decision factors were created: internal, transactional, and contextual benefits and internal, transactional, and contextual risks.

The second day, the committee members began by assigning importance weights to their decision factors. During this weight assignment, some participants argued for a more scientific weight elicitation procedure. The facilitator suggested other techniques such as paired comparisons, trade-off analysis, and regression estimates as suggested by Kleindorfer *et al*., (1993). After discussing the advantages and disadvantages of each method, participants agreed on using paired comparisons and AHP to determine the importance weight of their decision factors. Expert Choice (1990), an AHP-based software was demonstrated to the participants. After a brief introductory session and a couple of hands-on exercises, Expert Choice was used to capture committee member's judgments.

The standard procedure in QSPM required the determination of the attractiveness scores. QSPM defines an attractiveness score as a numerical value that indicates the relative attractiveness of a criterion for a given alternative. The range for attractiveness scores in QSPM is 1 = not attractive to 4 = highly attractive. Most of the participants thought this limited scoring range was unrealistic. Similarly, they perceived as

Table VI. Overall analysis

	Environmental weight	Criteria weight	Alternatives A	B	C	D	Ideal alternative
Benefits							
Internal environment	0.659						
ABP		0.033	0.90	0.50	0.50	0.50	0.90
ITK		0.088	0.50	0.70	0.70	0.20	0.70
RQI		0.452	0.70	0.90	0.20	0.20	0.90
OTD		0.267	0.90	0.70	0.20	0.20	0.90
IES		0.160	0.60	0.70	0.40	0.20	0.70
Transactional environment	0.263						
ICR		0.501	0.90	0.80	0.60	0.30	0.90
ICS		0.310	0.60	0.40	0.40	0.50	0.60
PCB		0.149	0.80	0.80	0.50	0.50	0.80
KJC		0.040	0.20	0.60	0.90	0.10	0.90
Contextual environment	0.078						
SGL		0.374	0.40	0.50	0.30	0.30	0.50
FER		0.571	0.40	0.60	0.40	0.20	0.60
JER		0.055	0.50	0.60	0.50	0.60	0.60
Total Euclidean Distance from the Ideal Benefit (B^m)			0.023	0.016	0.267	0.343	0.000
Risks							
Internal environment	0.229						
IRD		0.278	0.40	0.90	0.40	0.10	0.10
LPM		0.529	0.20	0.50	0.70	0.60	0.20
RTW		0.149	0.40	0.60	0.60	0.30	0.30
HET		0.044	0.60	0.70	0.40	0.30	0.30
Transactional environment	0.696						
JPI		0.066	0.60	0.70	0.70	0.10	0.10
HCB		0.066	0.30	0.30	0.90	0.10	0.10
CCS		0.557	0.30	0.70	0.70	0.70	0.30
LOF		0.311	0.50	0.70	0.50	0.40	0.40
Contextual environment	0.075						
BTE		0.134	0.60	0.70	0.70	0.10	0.10
JCD		0.134	0.30	0.30	0.90	0.10	0.10
CJR		0.692	0.70	0.70	0.50	0.70	0.50
PTF		0.040	0.50	0.70	0.50	0.40	0.40
Total Euclidean Distance from the Ideal Risk (R^m)			0.027	0.163	0.159	0.083	0.000

unreasonable the constraint that if a factor has no effect upon an alternative, then no attractiveness score can be assigned to the remaining alternatives. In addition, the committee felt more comfortable using probabilities of occurrence because the factors were defined as events.

The third day, the importance weights and the probabilities of occurrence were aggregated for each participant using a weighted sum method. Once the committee members were presented with their overall scores, they questioned the meaning of the data in the absence of a reference point. This motivated the facilitator to develop the ideal alternative (Schelling, 1960; Festinger, 1964; Zeleny, 1974, 1982). Using the ideal alternative and Euclidean distance, participants were able to visualize their choices on a two-dimensional graph and find their preference order for the alternatives. Once the individual rankings were identified, MAH was used to identify a consensus ranking of the alternatives for all the committee members. MAH forms consensus orderings that reflect collective DM agreement given ordinal or cardinal rankings. Normative averaging procedures could have been used to combine individual rankings. However, normative aggregation procedures (see, e.g., Aczel and Saaty, 1983; Steeb and Johnson, 1981) provide little stimulus for the exchange of opinions. Additionally, MAH was

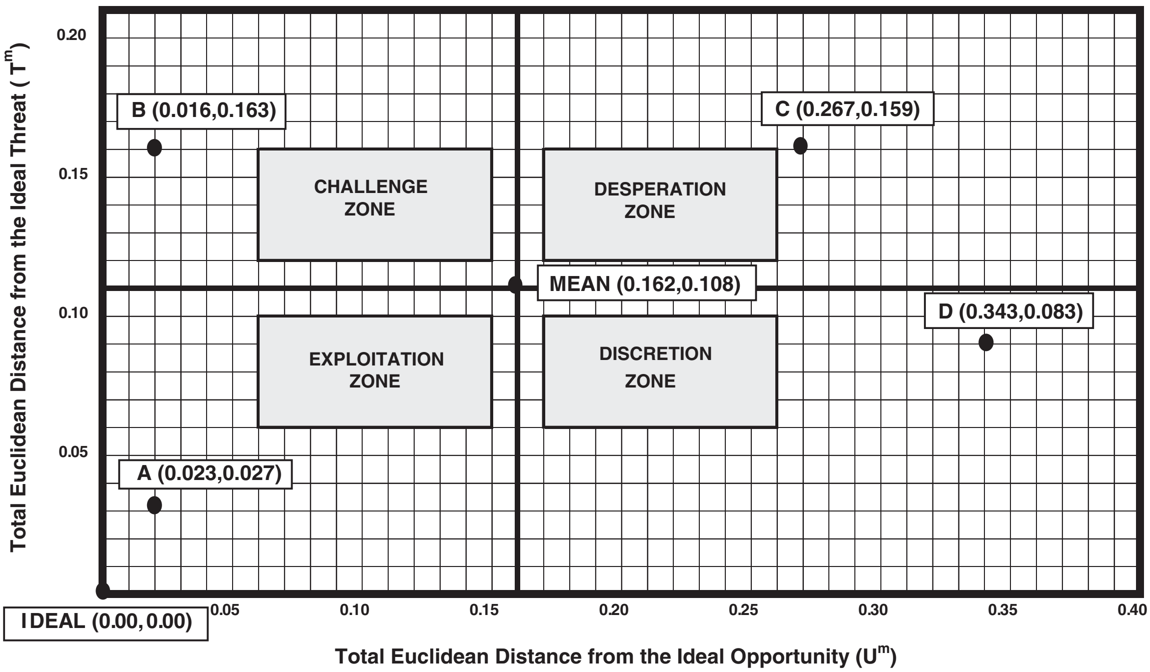

Figure 2. The four strategic alternatives (committee member 1).

selected as the consensus ranking procedure because of its simplicity, flexibility, and general performance.

6. MANAGERIAL IMPLICATIONS

A strategic assessment committee is responsible for the evaluation of strategic alternatives at Semicon. This committee is comprised of 12 members, most of whom are from senior management. The individual preferences from *Euclid* can be combined into group preferences using several approaches (Barzilai *et al.*, 1986; Blin and Whinston, 1974; Bowman and Calantoni 1973; Cook and Seiford, 1978). Cook and Kress (1985) proposed a network model for deriving the optimal consensus ranking that minimizes disagreement among a group of DMs. Ali *et al.* (1986) presented an integer programming approach to consensus ranking. While these techniques are complex, Beck and Lin (1983) have developed a simple analytical procedure called maximize agreement heuristic (MAH) to arrive at a consensus ranking that maximizes agreement among DMs. At Semicon, MAH was used in conjunction with an intuitive graphical approach.

Each committee member was given three reports in a graphical format depicting the individual's own preferences and both a summary and the details of the group preferences. The individual feedback shows how each alternative is positioned within the strategic zones based on the DM's assessment of its benefits and risks. Figure 2 shows the total Euclidean distance of the four alternatives from the ideal benefit and risk for committee member 1.

The committee members also received two reports representing the group's preferences. The summarized group feedback in Figure 3 shows the group's overall mean total Euclidean distance from the ideal benefit and risk for the four alternatives. Based on the group's assessments, alternative A falls in the exploitation zone, B falls in the challenge zone, C falls in the desperation zone, and alternative D falls in the discretion zone.

The detailed group feedback in Figure 4 shows the position of each committee member's preferences compared to the group's overall mean. For example, committee member 1's preferences place

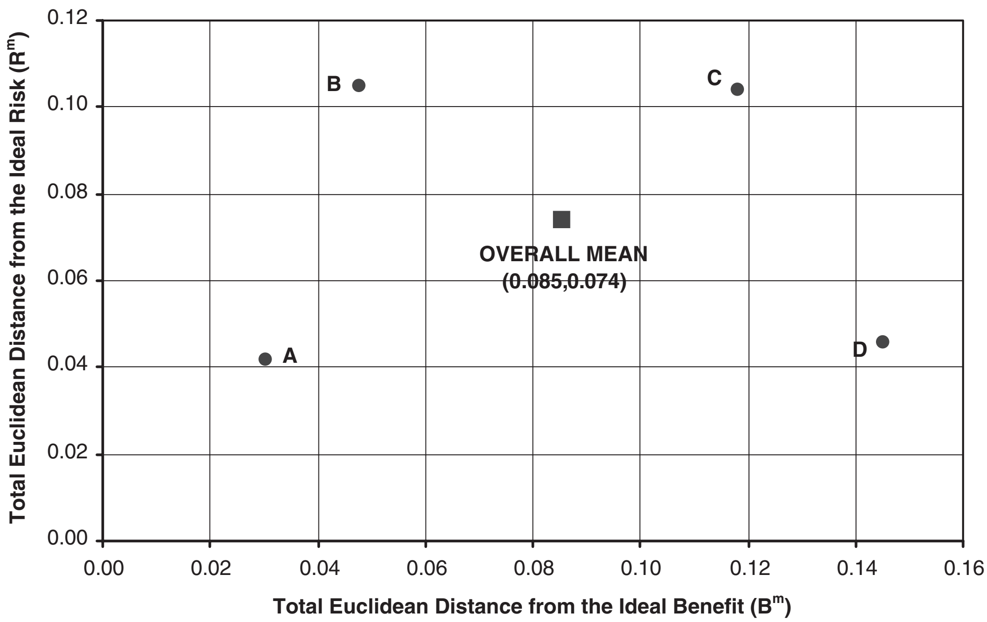

Figure 3. The Four strategic alternatives (average for all committee members).

alternative A in the exploitation zone, alternative B in the challenge zone, and both alternatives C and D in the desperation zone. Figure 4 also reveals 11 occurrences of alternative A in the exploitation zone, eight occurrences of alternative B in the challenge zone, five occurrences of alternative C in the desperation zone, and nine occurrences of alternative D in the discretion zone.

In order to develop a consensus ranking of all alternatives with MAH, the overall Euclidean distance of each alternative (D^m) was calculated for all 12 committee members. The individual committee member rankings along with the consensus ranking of the committee are presented in Table VIII. The MAH ranking for the committee is $A > B > C > D$.

After receiving the graphical and analytical feedback in Figures 2–4 and Table VIII, the committee met to finalize the decision. In this meeting, members were encouraged to share their views with other members of the committee. Given the feedback provided by *Euclid*, the strategic assessment committee at Semicon unanimously selected $A > B > C > D$ as their order of preference.

Prior to implementation of *Euclid*, QSPM was used to evaluate the strategic alternatives at Semicon. Although QSPM made significant contributions to the strategic evaluation process, increasing environmental complexities forced the committee to look for a similar but more comprehensive approach. Semicon needed an approach that combined the analytical and intuitive aspects, that was simple yet comprehensive and that was flexible enough to provide structure in a dynamic environment. *Euclid* was designed to provide these capabilities while allowing visual communication of output to the DMs and permitting them to perform sensitivity analysis.

A 10-item questionnaire was pre-tested and utilized to measure each committee member's perception of QSPM. This questionnaire contained a definition for each of the following ten attributes: analytical, intuitiveness, simplicity, comprehensiveness, flexibility, structured, visual, sensitivity analysis, decision process quality, and decision quality. The questionnaire employs a seven-point Likert scale with 1 indicating strong disagreement, 4 indifference, and 7 strong agreement (Lewis and Butler, 1993). The same questionnaire was given to the committee members after the implementation of *Euclid*. Table VII presents statistics describing the results of the questionnaires.

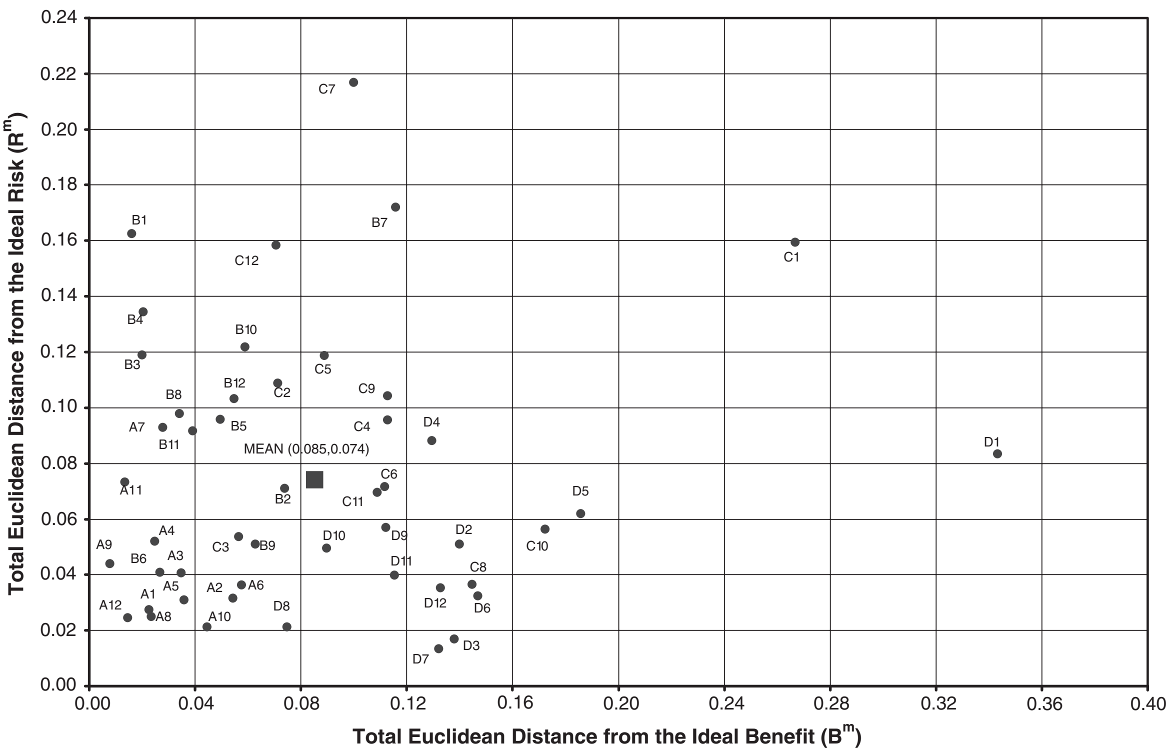

Figure 4. The four strategic alternatives (committee members 1–12).

One-sided Wilcoxon signed ranks test with $n = 12$ subjects and $\alpha = 0.05$ was used to compare the committee ratings. As it is shown in Table VII, the ratings of *Euclid* on the analytical, intuitiveness, comprehensiveness, visual, decision process quality, and decision quality were significantly greater than the QSPM ratings. There was no statistical difference between *Euclid* and QSPM ratings for simplicity, flexibility, structured, and sensitivity analysis at 0.05 significance level. The committee concluded that *Euclid* had significantly enhanced the decision process and their confidence in decision.

The common wisdom is that good decisions result in good outcomes, and poor decisions result in poor outcomes. A questionnaire was used to assess each committee member's perception of the process and outcome in QSPM and *Euclid*. The use of the questionnaire approach has been criticized by Eden (1995) and therefore should be applied carefully. Wright and Rohrbaugh (1999) critique various approaches to the evaluation of decision conferencing and suggest that evaluations should focus on processes rather than outcomes, address the group rather than individual roles and behaviors, and view the group in organizational context rather than in isolation. The competing values approach to organizational analysis can be used to enhance the quality outcome of group decision making (McCartt and Rohrbaugh, 1989; Reagan and Rohrbaugh, 1990). Ideally, the decision process and quality of *Euclid* could be compared with various competing methods. However, realistically, such an experiment requires a considerable amount of time and effort by a group of busy executives attending a 3-day decision conference. In sum, it should be noted that it is possible for a most unreasonable method to be linked over time with a windfall, while in another instance, for a most reasonable method to fall far wide of the mark.

7. CONCLUSION

Global competition, data availability, and advances in computer technology have made strategic decision making more complex than ever. *Euclid*

Table VII. Means and mean differences for euclid and QSPM

Attribute	Euclid mean	Euclid std. dev.	QSPM mean	QSPM std. dev.	Mean difference	Significant $\alpha = 0.05$
Analytical	6.17	0.72	2.67	0.78	3.50	Y
Intuitiveness	6.25	0.62	1.75	0.62	4.50	Y
Simplicity	4.08	1.00	4.92	0.90	-0.83	N
Comprehensiveness	6.17	0.83	1.83	0.83	4.33	Y
Flexibility	6.33	0.49	5.67	0.89	0.67	N
Structured	5.83	0.83	5.17	0.83	0.67	N
Visual	6.00	0.85	1.92	0.79	4.08	Y
Sensitivity analysis	5.92	0.90	5.17	1.11	0.75	N
Decision process quality	6.25	0.75	1.92	0.51	4.33	Y
Decision quality	6.58	0.51	1.75	0.45	4.83	Y

uses environmental scanning, AHP, subjective probabilities, and the theory of displaced ideal to reduce these complexities by decomposing the strategy evaluation process into manageable steps. This decomposition is achieved without overly simplifying the issues within the strategic decision. Previous strategic evaluation models tend to be either intuitive or highly analytical. While intuition is still favored by practicing managers, it may be dangerously unreliable when used to solve complex strategic problems. On the other hand, highly analytical models are often avoided or misused because of their technical difficulties. *Euclid* has several attractive features that address some of the limitations inherent in the existing models.

(i) *Analytical:* The value analysis model utilized in *Euclid* is considered a multicriteria decision making approach.
(ii) *Intuitive: Euclid* captures the intuitive preferences of DMs by using methods such as AHP and subjective probability estimation.
(iii) *Simple: Euclid* has a simple scoring system that is easy to understand.
(iv) *Comprehensive: Euclid* processes a wide range of information concerning the benefits and risks in the internal, transactional, and contextual environments.
(v) *Flexible: Euclid* does not limit the number of alternatives or environmental factors to be examined.
(vi) *Structured: Euclid* decomposes the strategy evaluation process into manageable steps and then integrates the results from each step to arrive at an optimal solution.
(vii) *Visual: Euclid* allows DMs to visually examine the benefits and risks of the strategic alternatives by comparing them with the ideal alternative.
(viii) *Sensitivity Analysis: Euclid* can be used in an interactive mode to perform ''goal seeking'' and ''what-if'' analyses.

Table VIII. Individual and consensus ranking of alternatives

Committee member	Order of preferences
1	A > B > C > D
2	A > B > C > D
3	A > C > B > D
4	A > B > C > D
5	A > B > C > D
6	B > A > C > D
7	A > C > D > B
8	A > B > D > C
9	A > B > D > C
10	A > C > D > B
11	A > B > D > C
12	A > B > D > C
Committee	A > B > C > D

Using a step-by-step and structured approach like *Euclid* does not imply a deterministic approach to strategic decision making. While *Euclid* enables DMs to crystallize their thoughts and organize their beliefs, it should be used very carefully. Managerial judgment is an integral component of *Euclid*; therefore, the effectiveness of the model relies heavily on the DM's cognitive abilities to provide sound judgments. *Euclid* utilizes intuitive methods such as subjective estimation of probabilities and weights because they cannot be supported by empirical analysis. While these judgments often mirror a DM's belief in the importance of certain events, they should be used with caution. As with any decision calculus model, the researchers and practicing managers must be aware of the limitations of subjective estimates. When empirical analysis is feasible and makes economic sense, it should be utilized to improve these estimates (Lodish, 1982). *Euclid* should not be used to plug-in numbers and crank-out optimal solutions. Potentially, DMs could make poor judgments as they do with any approach. Such judgments can generate misleading results and ultimately poor decisions.

Finally, practicing managers should be aware that the practical application presented in this paper suffers from the confusion between ''means'' and ''ends'' objectives (Keeney, 1992). Value-focused thinking suggested by Keeney (1992) can be used to eliminate this problem in future applications. Constructing objectives for decision problems is more of an art than a science and values play an important role in developing objectives. When DMs express a preference or justify an action, they typically refer to their values. Objectives are specific expressions of values. It is useful to distinguish between means and ends objectives. Ends objectives are the ones that a DM truly cares about. Ends objectives can be identified by asking why a DM cares about a stated objective. If the answer is ''That is self evident'', it is an ends objective. If the answer is ''Because achieving this objective contributes to achieving another objective'', it is a means objective. Means and ends objectives can be represented by a means-ends network (Keeney, 1992). The purposes of creating means-ends networks are to clearly distinguish between means and ends and to clarify their causal relationships. Keeney (1992) provides a more detailed list of questions that are useful to elicit objectives. Hammond *et al*. (1999) provide additional guidance on how to identify objectives. Means and ends objectives can be distinguished in *Euclid* by considering the overall internal, transactional, and contextual concerns as end objectives and those objectives that contribute to each environmental concern can be considered as the mean objectives.

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