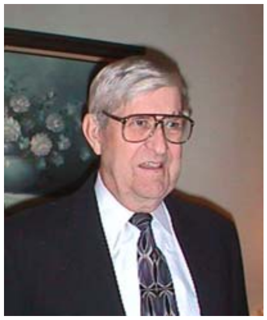
Combinex® — A Method for Sound Decisions



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THE EVOLUTION OF VALUE ANALYSIS

"***Biggest Thing Since Mass Production***" said the headline in the January, 1964 issue of *The Reader's Digest*. This first national publicity on the process of Value Analysis (VA) described only the basic elements of Lawrence D. Miles'[1] invention. The article spoke of cost reduction and it touched upon the rule against lowering performance. This was clearly not the highly evolved VA of today, yet it was suggested that the process "*may prove one of the greatest boons to consumers since Henry Ford . . .*" What could there be about this new technique, having only recently moved beyond the competitive confines of the General Electric Company, which could cause such hyperbole in the nation's largest periodical?

Think in terms of the old bromide about real estate: "Location, Location, Location!" — Except that with VA it's "Results, Results, Results!" Miles' original work at Schenectady had been amazingly effective in improving the value of the electrical devices that were the heart of the GE product line of that day. The past fifty years have seen major improvements in the process, but even original, "old-style" VA was impressive enough that GE invested eight million dollars in developing the process.

When Miles, the Nebraska school teacher/bank cashier decided to go for an EE degree, the wheels were set in motion for the inevitable development of VA. It didn't all come together though until he had spent a creative and inquisitive 6 years at the General Electric Company. His famous *"Doesn't anyone at General Electric care what things cost?"* outburst came in 1938, starting his 10-year search for a system which would both identify and then remove excess cost from products. In 1948, the system received both its name and blessing as Value Analysis by Harry Winne, GE's Engineering VP.

What was the state of VA at this stage in its development? Was it today's highly structured problem-solving process? Did it require teams? Structured Creativity? Function-structuring? Decision-structuring? Implementation-planning? The answer to all of these leading questions is, quite simply, "No."

What Miles' remarkable insight had led him to invent was the kernel of a truly effective and fundamentally unique problem-solving system. At its heart was the elemental form of Function Analysis. It was left to others to flesh out Miles' nascent system with Eugene K. Von Fange's, and later Alex Osborn's system of creativity; with the Arthur Koestler principles of Focused Creativity; with Thomas J. Snodgrass's customer focused Value Control Concept; with Charles W. Bytheway's system of FAST function logic Diagramming; with the Xerox-developed Champion Principle; with Carlos Fallon's Combinex® decision-making system; and with the endless string of additional enhancements over the past fifty years which have elevated a truly landmark method into its present status as ***The World's Most Effective Problem-Solving System***.

This paper focuses on only one of these added features, the decision-making system developed by Carlos Fallon called Combinex®.

HOW DOES COMBINEX® FIT IN?

In the Synthesis Phase of the Value Analysis Job Plan, the innovative *words* and *phrases* of the Creative Phase are elevated into *ideas* and *concepts*. The team then takes a three-week break during which each member thoroughly investigates each of the ideas or concepts she/he has volunteered to champion. In the following Development Phase, the team decides which of the surviving Synthesis Phase concepts will be pursued. The ideal method for making these selections makes use of Combinex® and a set of Management Selection Criteria. These are objective, mutually exclusive, evaluative criteria with associated weights, ***which are defined by operating and executive management***.

Decisions

At this stage in the value analysis process, the teams are commonly faced with a new kind of problem; they have several optional solutions to the same problem. Which one is best?

Each of us is faced with hundreds of similar situations each day of our lives: What shall I wear today? What shall I have for breakfast? Shall I buy fuel on the way to work or later? What shall I work on first? Next? None of these questions is earthshaking in its implications, but collectively, the decisions we make each day significantly affect the outcome of the day for us, and often for those with whom we interact. Indeed, the collective quality of those decisions, each day, each week, each year, defines our total effectiveness as people.

If we can assume that each of us is, indeed, effective in our life and in our career, then we must each have a pretty good system for making those hundreds and thousands of decisions.

Just what is that system?

What logical process do we activate when we are forced to make a choice between two or more alternative actions?

"I look at all the options and I choose one. It usually turns out to be the right one.

"I consider all the variables carefully, and the answer is usually obvious."

"I Just do what feels right to me."

These are actual responses from people who are successful managers. These people make good decisions, but they don't know what process they are using.

A Science of Decision-Making?

In the mid-1950s, the new management science of operations research and the arrival of the high-speed computer triggered at least a dozen automatic decision-making systems. Each was touted as both easy to use and rigorous. Most were neither.

In the early 1960s, the late Carlos Fallon[2], Manager of Value Analysis at RCA, developed the first truly easy-to-use and rigorous system. Fallon was a rare combination of down-to-earth practitioner, mathematician, philosopher, and mesmerizing public speaker. His insight gave us Combinex®, which he published nationally in his book *Value Analysis to Improve Productivity* (FaIlon 1971). Fallon's work has been expanded and modified in the description below.

> ***NOTE***: The correct time to apply Combinex® is ***before the start*** of a VA study. This is in keeping with the concept that, in the Modern Value Analysis Job Plan:
>
> "***IMPLEMENTATION IS THE FIRST STEP***"
>
> In problem-solving systems, it has been customary to list the Implementation step as the last activity. It is obvious upon reflection that there is a timing problem here. If one waits until the end of the problem-solving process to define what must be done during the process to assure implementation, it is often too late to take any corrective action. The up-front implementation session identifies each of the possible areas in which changes might be developed and then identifies all of the potential blocks to implementation. It then finally, establishes what must be done during the problem-solving process to either forestall or to overcome these blocks.
>
> Combinex® ideally fits these constraints. It is used prior to the study to establish *Management Acceptance Criteria* with their associated limits so that the study team members may develop their proposals for alternatives within constraints representing the viewpoints of management. Combinex® is unique in having this capability to guide the study team in their problem-solving activity by supplying them with the collective internal viewpoints of the ultimate decision-makers. Other available processes of decision-making require that the problem-solving process be complete and all alternatives detailed before the process may be used to identify the optimum solution.

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COMBINEX®

Created by Carlos Fallon

Modified for Direct Magnitude by

Theodore C. Fowler, CVS, Fellow, SAVE[3]

By using the Combinex® system, one can determine which of one's solutions are truly the best from an objective viewpoint, and further, one can prove it to others who might question the decision.

While Combinex® is an easy-to-understand, easy-to-administer, orderly process for making decisions, its effectiveness lies in its ability to show clearly how the answer was obtained, and how the attitude of the decision-makers helped to shape those results.

The following five steps define the Combinex® process. Each is explained in detail on the following pages.

1. **Select criteria.**
2. **Define limits, reference level, and sensitivity curves.**

3. **Establish weights, or relative importance factors.**
4. **Rate each alternative on each criterion.**
5. **Calculate relative "figures of merit."**

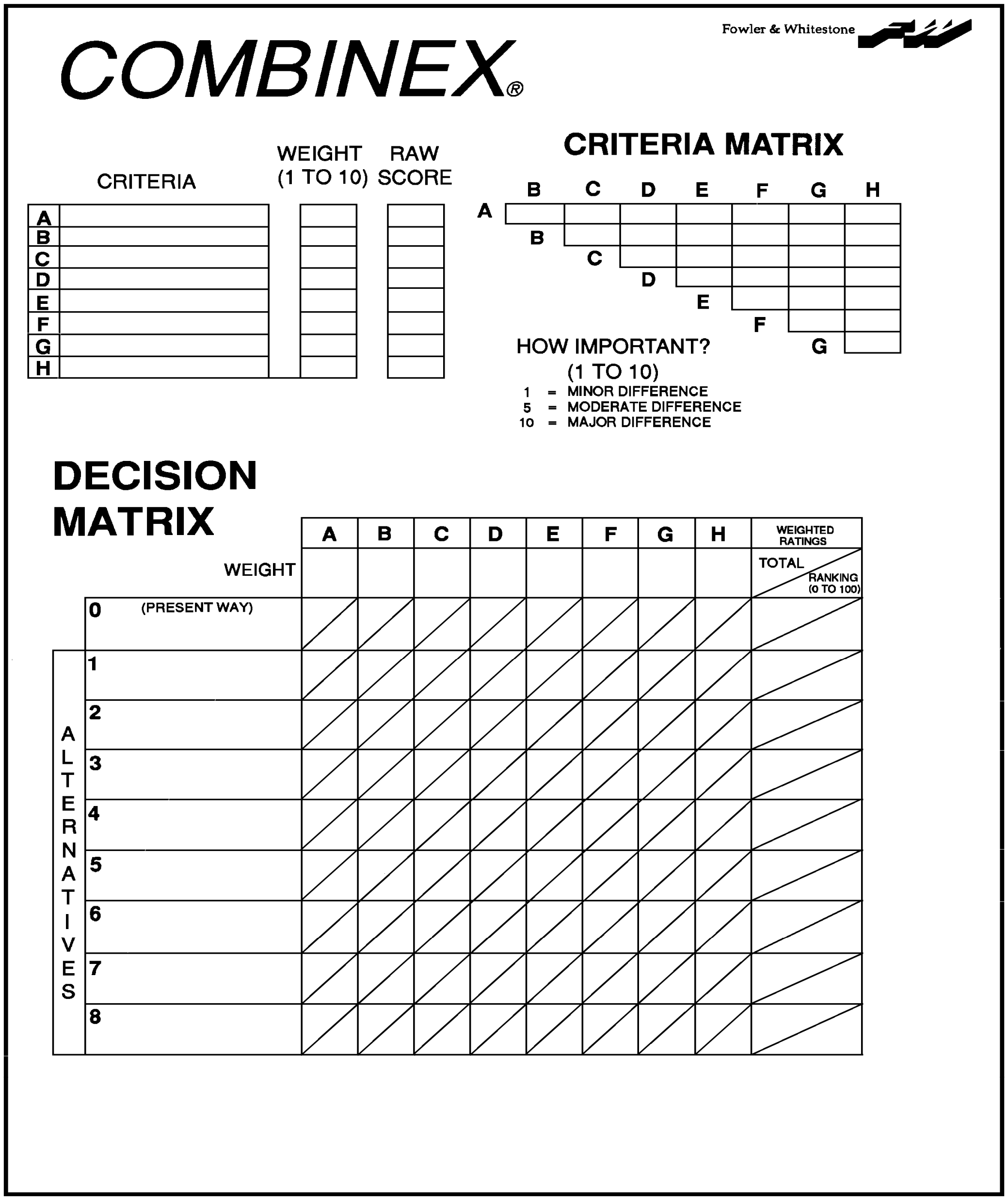

Figure 1. The Combinex® decision matrix form
summarizes all decision data on a single sheet

The forms shown in Figures 1 and 2 will guide the analyst through the procedure. Excerpts from these forms illustrate the process as described below.

Step 1: Select Criteria

To start the evaluation process, first select the evaluative criteria that will affect the outcome. Use a form such as Figure 2 to collect all data on each of the criteria.

Note that *evaluative criteria* are simply a set of objective standards by which to judge the worth of alternative solutions to a problem. Three considerations control the selection of criteria.

First, The decision-makers, that is, the persons who have the authority to approve the final selected alternative solution, must ultimately select the criteria.

Second, criteria must be measurable. Ideally, they should be parameters. Some examples of measurable parameters when working with a product are as follows;

Performance (in terms of measurables such as reliability in MTBF, maintainability in MTTR, level of accomplishment of basic or supporting functions)

Cost (in terms of level of investment required, manufacturing cost, service cost, total cost, ROI, net present value, cost versus target, cash payback, and so on)

Risk (where it can be quantitatively appraised)

Affect on Safety

Feasibility in terms of probability of accomplishment

When working with processes or procedures, criteria are often less concrete, and therefore are more difficult to measure. In our experience, however, *all* criteria are susceptible of measurement. A recent resource, which addresses this challenge, is Stewart[4]. Examples of measurable parameters when working with processes are as follows:

Adaptability	Attractiveness	Novelty	Initiative
Stylishness	Eco-Friendliness	Political Acceptability	Neatness
Convenience	Satisfaction	Texture	Comfort

The metrication of abstract criteria is accomplished through establishment of several points on a curve and then the definition of each of those points with short statements.

Third, criteria must be independent, that is, mutually *exclusive*. Use the following process to identify key criteria and to assure their independence:

Freewheel. Temporarily defer judgment as in a creative problem-solving session. Record all conceivable criteria. If you are not the decision-makers, attempt to second-guess those who are by putting yourself in their place.

Judge. Through combination and evaluation, select a group of criteria that are sufficiently broad, measurable, and mutually exclusive to represent a best estimate of the measures by which the decision-makers will evaluate the alternatives. Remember that in the end, the decision-makers will have to agree with your choices.

Record. Record the name of each selected criterion on a form similar to that shown in Figure 2, using as few words as possible.

Define. Define the selected criteria by recording, on each form, those constraints necessary to make each criterion clearly mutually exclusive. Add brief notes to ensure that each person involved in the decision and each person who may evaluate the results will perceive each criterion in the same frame-of-reference.

Step 2: Define Limits, Reference Level, Sensitivity Curve.

This step comprises five tasks.

First, set upper and lower limits to establish the range over which valid decisions can be made. The lower limit is the *minimum acceptable*, the lowest level or worst condition that can be permitted. The upper limit is the *maximum possible*, the highest level or best condition that can effectively be used, or the most available, whichever is less.

Occasionally, the minimum acceptable is numerically high, while the maximum possible is numerically low. An example is where product cost is the criterion. Here, the highest level or best condition for the criterion is clearly the lowest dollar cost.

Second, establish a "reference level." Where it can be established, this will aid in defining the curve. It also simplifies both the tasks of weighting the criteria and rating the alternatives.

The reference level can be one of the following points:

- midpoint—center of the range
- typical—usual value of the criterion
- present value—current or known value of the criterion

Use whichever point is most significant.

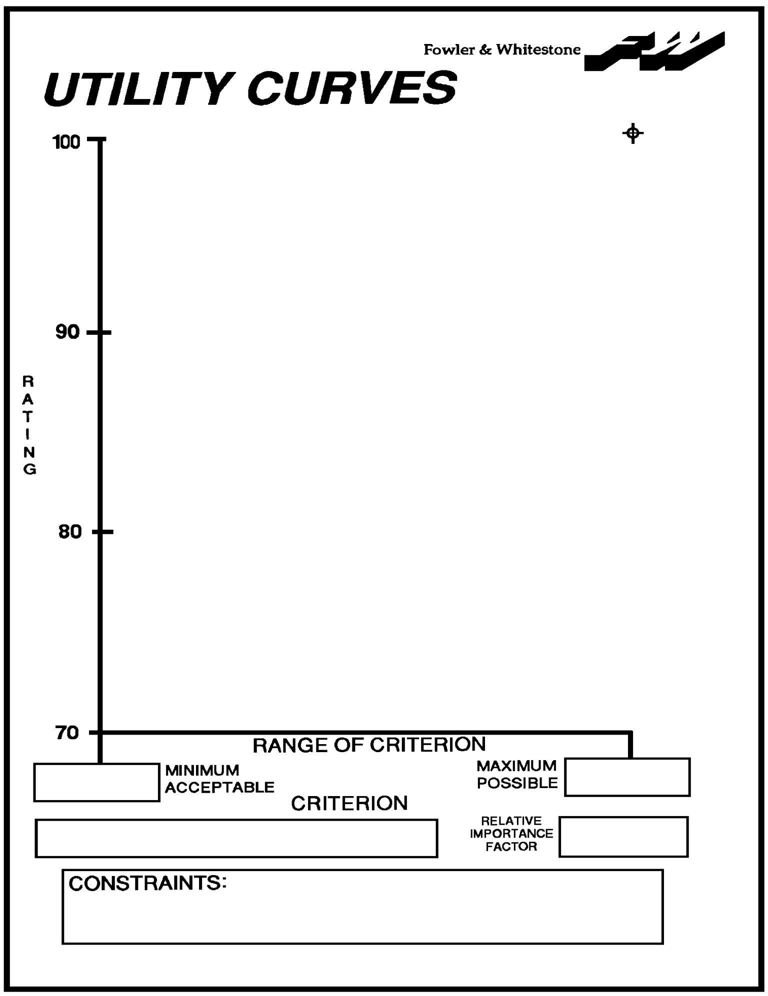

Figure 2. The criteria utility curve, including max and min limits, is essential to the paired comparisons process

Occasionally, there is no present value, and neither the term midpoint nor the term "typical" has any valid meaning. In such a case, the reference level is ignored and the limit values described below are used as references in performing the weighting of the criteria and the rating of the alternatives.

Third, enter the limits and reference level. Establish a horizontal and vertical scale on a criterion form such as the one illustrated in Figure 2 above.

Enter on the abscissa (x-axis) the lower and upper levels of the value of the criterion. Also enter on the abscissa the reference level of the value of the criterion, if one has been set. The range of the ordinate (y-axis) is always 70 to 100 to imply a typical rating range from “just passing” to “outstanding.”

Fourth, define the curve. Add to Figure 2 a curve that describes the variation in the influence of the criterion between its limits. In many cases, a linear relationship exists between the acceptability of an alternative solution and different values of the criterion. In others, the relationship is nonlinear, or even discontinuous. Develop a curve describing this relationship throughout the 70—100 range of the standard scale.

Establish the shape of the curve through a combination of two methods. First, determine the rate of change of the criterion at three points: the lower limit, the reference level, and the upper limit. Simply estimate the effect on the rating of a small change in the value of the criterion at each of these points. This defines three slopes from which a curve can be created. The other method is to rate the criterion at several different values. Draw a “best fit” curve through the points.

Fifth, review criteria. At this point, if you are not the decision-maker, review the criteria and curves with them. Do not proceed until the decision-makers have agreed that the data represents their criteria and curves. There are two important reasons for this: It is *not* possible to place oneself completely in another person’s place, and the decision-maker later will be more inclined to accept your recommendations if they are involved at this point.

Example:

A group of decision-makers defined on a flip chart a list of 8 criteria, reduced from an original list of 19 through a process of combination and redefinition based on the fundamental principle of mutual exclusivity. These are the criteria that next will be weighted

- **Manufacturing cost**
- **Minimum size, weight**
- **Risk**
- **Investment required**
- **Efficiency**
- **Ease of installation**
- **Ease of maintenance**
- **Field adaptability**

Step 3: Assign Weights

In the Combinex® process, two steps virtually determine the outcome: the selection of the criteria and the relative weighting of those criteria. Of the two, selection presents the fewest problems.

When the relative importance or *weighting* of criteria is established on the basis of simply the best judgment of the person or team performing the evaluation, three sources of error are always present.

One is provincialism, or self-interest. This is the error caused by the different frames of reference or viewpoints of the evaluator and the decision-makers. Essentially, this is partiality, bias or prejudice in favor of whatever is familiar to each. Provincialism is obviously not present when the decision-makers are personally establishing the relative weighting.

Another is <u>subjectivity</u>, or emotion-based preferences. Their effect can be minimized with effort, but never eliminated.

The third is <u>complexity</u>. When more than two criteria are being compared, the process requires the simultaneous mental rating of a very large number of factors. The human mind is not capable of rationally interrelating so many permutations.

A technique that eliminates the *complexity* and greatly minimizes *provincialism* and *subjectivity* is called paired comparisons.

This method initially assumes that all criteria have equal importance. Each is then forced in turn into a comparison with each of the others. With each pair thus formed, a judgment is made as to which is more important to the decision-maker. An estimate is also made of the magnitude of that difference in importance.

These comparisons are made within two frames of reference, and the final decision is made on the combined bases of both comparisons.

In the first frame of reference, compare each pair at the reference level, if one has been set. Hypothesize an equal *decrease* in the value of each criterion from its respective reference level. The more important criterion is the one in which this decrease most affects the acceptability of typical alternative solutions. Repeat the procedure, hypothesizing an *increase* in the value of each.

In the second, compare each pair at the upper and lower limits. Perform the above evaluation at the upper limit, hypothesizing a decrease. Repeat at the lower limit, hypothesizing an increase.

Reference-level comparison (the first method) is the better one to use, particularly when the reference level represents the typical or present value.

The results of the forced-pair comparisons (A to B, A to C, and so on) are calculated and entered to give a relative importance factor, or weight, for each criterion (Fig. 3).

	B	C	D	E	F	G	H
A	A - 8	A - 2	A - 7	E - 4	A - 3	A - 5	A - 10
B		0	B - 3	B - 10	B - 6	G - 4	B - 8
C			C - 5	E - 9	C - 10	G - 8	G - 5
D				E - 6	D - 5	D - 4	D - 2
E					E - 9	E - 3	H - 10
F						F - 4	H - 9
G							H - 7

	RAW SCORE	WEIGHT (1 TO 10)
A	35	10.0
B	27	7.7
C	15	4.3
D	11	3.1
E	31	8.9
F	4	1.1
G	12	3.4
H	19	5.4

HOW IMPORTANT? (1 TO 10)

1 = MINOR DIFFERENCE
5 = MODERATE DIFFERENCE
10 = MAJOR DIFFERENCE

Number of decisions = n + (n-1) + (n-2) . . (n-n)

CRITERIA

A	INVESTMENT REQUIRED	E	EFFICIENCY
B	RISK	F	FIELD ADAPTABILITY
C	MANUFACTURING COST	G	EASE OF INSTALLATION
D	MINIMUM SIZE, WEIGHT	H	EASE OF MAINTENANCE

Figure 3. This paired comparisons criteria weighting form is filled in to represent a typical set of data involving eight previously determined criteria.

The procedure for this is to enter the letter of the criterion judged to be most important at each intersection on the weighting matrix. Add to that letter a number (1 to 10) signifying how much more important. If both are equally important, enter a zero.

For example, the first matrix entry in Figure 3, "A-8," is at the intersection of row A and column B. This indicates that criterion A is more important than criterion B by a factor of 8 (on a scale of 1 to 10).

The raw score shown in the rectangle on the right is the sum of all the As (35), Bs (27), and so forth. If any raw score is zero, enter, as the raw score for that criterion, an amount equal to one-half of the lowest value shown for any of the other criteria.

The weight is determined by rescaling the raw scores into a 0 to 10 scale. The criterion with the highest raw score is given a weight of 10, while the others are proportioned to that highest score For example, the weight of criterion C, manufacturing cost, in Figure 3 is calculated as shown in Figure 4.

Raw Score of "C"	÷	Raw Score of "A" (The Highest Scoring Criterion)	=	Weight
15	divided by	35	equals	.43

Multiplying **.43** by **10** (to rescale the weight on a 1 to 10 basis), results in **4.3**, the weight of Criterion **"C"**.

Figure 4. In this example, the formula is used to calculate the weight of criterion C, manufacturing cost

Step 4: Rate Each Alternative on Each Criterion

The team will then use a decision matrix (Fig 5) to compare and evaluate alternative solutions

To create this matrix, list the criteria with their associated weights across the top and list alternative solutions down the left.

Next, rate each alternative against each criterion, entering the rating (70 to 100) in the appropriate block. Ratings are obtained by picking values from the utility curves.

Step 5: Calculate the Relative Figures of Merit

Multiply each rating by the weight for the criterion, and enter the result in the same block. Separate the un-weighted and weighted ratings with a diagonal line.

HEAT EXCHANGER

		A	B	C	D	E	F	G	H	WEIGHTED RATINGS
	WEIGHT	3.4	3.1	4.3	7.7	8.9	1.1	10.0	5.4	TOTAL / RANKING (0 TO 100)
	0 (PRESENT WAY) ALUMINIZED TUBING	70 / 238	100 / 310	72 / 310	98 / 754	73 / 650	– / –	– / –	90 / 486	2748 / 91
ALTERNATIVES	1 TUBULAR	72 / 245	100 / 310	70 / 301	100 / 770	70 / 623	– / –	– / –	95 / 513	2896 / 92
	2 CLAM SHELL	90 / 306	72 / 223	92 / 306	74 / 570	88 / 783	– / –	– / –	82 / 443	2631 / 88
	3 HEAT PIPE	88 / 299	72 / 223	82 / 353	90 / 693	100 / 890	– / –	– / –	100 / 540	2998 / 100
	4 CORRUGATED FIN TUBE	75 / 255	80 / 248	74 / 318	98 / 755	93 / 828	– / –	– / –	70 / 378	2782 / 93

(A hyphen indicates that the criterion does not apply)

CRITERIA

A	INVESTMENT REQUIRED	E	EFFICIENCY
B	RISK	F	FIELD ADAPTABILITY
C	MANUFACTURING COST	G	EASE OF INSTALLATION
D	MINIMUM SIZE, WEIGHT	H	EASE OF MAINTENANCE

Figure 5. A completed decision matrix rates four different approaches to a heat exchanger problem.

Total the weighted ratings horizontally for each alternative. The result is the figure of merit for that alternative

Finally compare and select alternatives with high figures of merit. Note that a very small difference in the numerical figures of merit (on the order of 2 percent) is not significant, but as the difference approaches 5 percent it becomes significant. Avoid the tendency to choose an alternative with a significantly lower figure of merit simply because it instinctively feels better

SUMMARY

While the alternative with the significantly higher figure of merit is, initially, the so-called winner, the true power of the method stems from the unparalleled visibility of the data. On a single sheet are displayed all three of the factors that contribute to the final choice: *criteria*, *weighting*, and *rating*. Analysis of the anatomy of the data often develops an unprecedented insight for both the value team and the decision-maker.

In addition, Combinex® is a powerful selling tool. It closes the loop with the decision-makers. Recommendations to top managers that are presented in terms of their own acceptance criteria are far more likely to be well received.

WHY COMBINEX®?

Combinex® takes time. There is often a temptation to shortcut the process. “Why bother with all those time-consuming paired comparisons?” you ask. — And “What’s with all those limits and reference levels and ordinates and abscissas?”

The answer, simply stated, is that the rigor is essential. Without it, results are often dramatically wrong. As has so often occurred with the VA process itself, a newcomer to Combinex® is often guilty of actively ignoring certain of the standard elements because they either (1) seem unnecessary or (2) appear to be too time-consuming or "difficult to sell." As a result, we often see corrupted versions of Combinex® sold as the real thing. The resulting misunderstanding can be annoying to a practitioner, but it can become truly frustrating when the mis-user of the process then condemns the process as "unsound."

The need for rigor can best be verified through the classic process of comparison. My mentor, Lawrence D. Miles, recognized comparison as the most fundamental method of evaluating functions. Miles has said that “if there is no comparison, there is no evaluation” (Miles 1961). He regularly demonstrated the concepts of product worth and cost through “evaluation by comparison.” He would pass around a simple machined piece and ask each participant to estimate its manufacturing cost. The estimates often ranged over a ten to one range. He used this exercise to set the stage for the exposition of the rigorous metrics of his system of Value Analysis.

I shall use comparison as an effective method of exemplifying the need for rigor when applying the Combinex® process. The following example is a record of my experience with a recent client:

<u>Example</u>

In evaluating several alternative solutions to a problem in the selection of a person to be promoted to a higher management position, the following 12 criteria were suggested:

friendliness	experience	likeability
financial knowledge	education	reputation
initiative	references	appearance
knowledge of product	creativity	record

This "brainstormed" list of attributes was combined and refined until each complied with the rules of *measurability* and *independence*. Brief, detailed definitions were prepared for each of the eight resulting criteria, and utility curves and ranges were prepared for each.

As an experiment, the team was first asked to simply use their judgement to rate, on a scale of 10, the relative importance or *weight* of each criterion. They were given no guidance in how to perform this rating, and came up with the following:

Appearance	**8**	**Likeability**	**8**	**Education**	**8**
Experience	**10**	**Record**	**9**	**Initiative**	**7**
Communication	**7**	**Compatibility**	**8**		

The team was then guided through the Combinex® weighting process using the method of *paired comparisons* and arrived at a starkly different result:

Appearance	**3.2**	**Likeability**	**1.8**	**Education**	**2.7**
Experience	**4.6**	**Record**	**4.1**	**Initiative**	**7.7**
Communication	**10.0**	**Compatibility**	**8.4**		

When team members were asked to reason out the causes of the differences in the two ratings, they said that they felt that the method of *paired comparisons* appeared to be the solution to a previously unappreciated problem: *That it was impossible for them to simultaneously compare eight criteria and all of their consequences*.

It was also clear to them that "just using their judgement" gave them an invalid picture of the differences in importance between criteria. For instance, the objective *paired comparisons* approach using the full scale of 1 to 10 gave them the surprising revelation that **Communication** was the most important criterion, not **Experience**, and that, for instance, **Likeability** was only one fifth as important, and **Education** was less than one third as important.

They concluded that, when "just using their judgement," their instincts were apparently pushing them to conclude, "If it's important enough to be on the list, it must be at least a seven!" When they reflected on their whole *weighting* experience, each of them was convinced that the *paired comparison* ratings were far more valid.

In their later ratings of candidates the group was able to document very significant differences in "figures of merit," making their final selection of a candidate for promotion totally obvious.

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4 Stewart, Robert B., *The Integration Of The Performance Measures Process Into Value* Studies, SAVE International Proceedings, Dayton, 2004.

EPILOGUE

I was recently informed that if I reached the age of eighty, I would enter my "dotage." In celebration of this achievement, scheduled for September 23, 2005, I hereby bequeath this paper to the public domain as of that date. I encourage anyone to copy and distribute this document in any form. Should a prospective user find it difficult to copy this in its present Adobe Acrobat format, I will be pleased upon request, to email to anyone a copy in Microsoft Word format.