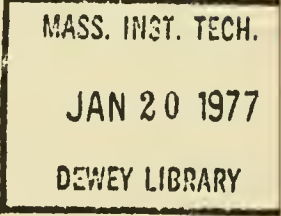# WORKING PAPER
## ALFRED P. SLOAN SCHOOL OF MANAGEMENT

INDUSTRIAL ADOPTION OF SOLAR AIR CONDITIONING:
MEASUREMENT PROBLEMS, SOLUTIONS AND
MARKETING IMPLICATIONS

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and

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WP 894-76                    December 1976

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## Abstract

Industrial adoption of capital goods typically involves several indi-
viduals with different backgrounds and job responsibilities.  These indi-
viduals differ in the way they perceive and evaluate available product
alternatives.  The measurement and consideration of these differences can
lead to substantial improvements in the development of marketing strategies
for new industrial products.

This paper analyzes the introduction of solar powered air conditioning
aimed at the industrial market.  Individuals most likely to be involved in
the adoption process are identified and differences in their perceptions
and evaluation criteria are measured.  The investigation of these problems
leads to new measurement methods and to some new tests for determining the
equality of evaluation spaces.  Implications for the development of a market-
ing plan for industrial solar air conditioning are discussed.  The potential
for application of the new methodology to development of marketing programs
for other industrial products is also reviewed.

A significant difference between individual and organizational adoption of energy alternatives (or, in fact, products of any sort) is that organizations typically have several individuals involved in the adoption process. These individuals differ in both their perceptions of available product alternatives and their evaluation criteria. Specific consideration of these differences in a product development procedure leads to improvements in product positioning and opens new marketing strategy alternatives. This paper suggests how differences in product perception and evaluation criteria can be measured and how those measurements be used to improve market entry strategy for solar powered, industrial air conditioning systems.

## 1. Solar Energy Alternatives

Currently, over 25% of the energy used in the U.S. is consumed by heating and cooling of buildings and by providing hot water (Westinghouse phase 0 report [31 ]). At a conversion efficiency of 10%, 11,000 square miles of solar collectors (or 0.3% of U.S. land area) could have satisfied the 1970 water and space heating and cooling needs of the U.S. (Williams [33]). In light of increasing costs and diminishing supplies of fossil fuels as well as our professed need for energy independence, solar energy is an alternative to be considered.

A recent study compared the cost of conventional and solar space heating, amortizing the solar system capital cost over 20 years at 6% interest, and found that even at $2/ft$^2$ for solar collectors (an optimistically low price) there are few U.S. areas where such systems are cost effective currently (Tybout and Lof [28]). The greatest near term use of solar energy seems

to be in water heating. About 4% of the U.S. energy consumption goes for water heating. (Westinghouse phase 0 report [31]). Water heating is also a simple and effective application of solar technology and there is much literature regarding its feasibility and efficiency (Daniels [8]). In fact, there are over 2.5 million solar water heaters now in use in Japan and over 100,000 in Israel (Williams [33]).

Solar water heating systems have not been adopted in the U.S. in any major way even in the South or Southwest;  there are now about 8,000 such systems currently in use in the southern U.S. (New England Electric System [23]). Why aren't there more? Certainly there are key economic and financial considerations hindering adoption of these systems:  they cost the consumer more now, although they promise future savings. A significant amount of research has centered around constraints and incentives surrounding the adoption of solar heating and cooling equipment (see Arthur D. Little [19] report, for example). Little of this research, though, focuses on noneconomic factors affecting adoption. An exception is a report on the market potential for solar water heaters in New England which suggests that personal, lifestyle and system-design characteristics strongly affect consumers' propensity to adopt solar water heaters (Lilien and Johnston [18]).

Although immediate prospects for an economically viable solar-powered alternative are not great, it is important to note that space cooling is the fastest growing area of U.S. energy use, projected to account for over 5% of U.S. energy demand by 1980. (Westinghouse phase 0 report [31]). The greatest portion of this demand is for use in industrial buildings. Thus, a considerable amount of fossil fuel could be saved by wide scale adoption of solar powered cooling systems.

System economics are important factors affecting industrial adoption.
But, as in the case of solar water heaters, non-economic factors are important
as well; Lehmann and O'Shaughnessy [16] indicate that price is not the primary
determinant of supplier in most industrial purchasing situations.  Non-
economic factors affecting solar air conditioning adoption include:

- reliability

- sensitivity to climatic conditions

- company image

- protection against fuel rationing

- system complexity

- protection against power failures

- etc.

(see Lilien [17]).

It is entirely possible that a so-called cost effective solar air con-
ditioning system may not be adopted for non-economic reasons or, conversely,
that a system may be adopted that is not cost effective due to some of the
non-economic considerations indicated above (Lilien [17]).  A detailed under-
standing of these issues is an essential input to development of an effective
marketing strategy.

## 2. Industrial Adoption of Energy Saving Alternatives

The industrial adoption process differs from the consumer adoption process in several respects. First, organizational buying decisions usually involve several people with varying preferences, and perceptions and whose responsibilities differ. Second, industrial purchasing decisions tend to involve more technical complexities related to the specific product being purchased. Third, the organizational adoption process can be separated into phases more easily than the consumer adoption process, as different individuals are usually associated with different phases. Finally, these decisions typically take longer to make, leading to lags between the application of marketing strategy and buying response (Webster and Wind [30]).

Figure 1 describes a conceptual model of the industrial adoption process for capital equipment. It is based on the assumption that the firm has recognized the need for a product from the class under study, and that the adoption decision results from a systematic decision-making process.

According to the model, environmental and organizational constraints influence the purchasing decision process by limiting the number of product alternatives of which decision participants are aware and which also satisfy organizational needs. The resulting set of feasible alternatives is the choice set of the organization, over which individual perceptions and preferences are defined. The last element of the model links individual preference to group preference through group interaction procedures. Choffray and Lilien [4] develop models of the group selection of a specific alternative from the firm's feasible set.

Choffray [5] suggests that two major sets of measurements are needed to calibrate industrial market response models: those dealing with the structure

of the adoption decision process and those dealing with the differences in perception and evaluation criteria among participants in that process.

Questions dealing with the structure of the adoption process and the identification of clusters of organizations that exhibit similar patterns of involvement in their adoption process are dealt with elsewhere by Choffray [ 5 ]. Here we treat the critical problem of how participants in the adoption process for energy saving equipment differ in the way they perceive and evaluate available alternatives.

Choffray's [ 5 ] work on microsegment analysis suggests that the potential market for industrial air conditioning systems can be segmented according to what individual responsibilities are most likely to be involved in the decision process. This information is critical to the development of sensible marketing strategies for new industrial products, especially if decision participants who exert similar responsibilities in their respective organizations do in fact _differ_ in the way they perceive and evaluate available product alternatives. A similar concern about the differential perception of innovations by different groups of individuals involved in their adoption was also expressed by Rogers and Shoemaker [24].

The problems we investigate in the next sections, then, are:

1. How do these different groups of potential decision participants differ in the way they _perceive_ available alternatives, including the new air conditioning system?

2. How do these groups of decision participants differ in their _evaluation criteria_?

3. What evaluation criteria most heavily affect product _preferences_ for each of these different groups of individuals?

The development of methodology to systematically, consistently and accurately answer these questions is the key problem addressed in this paper.

# FIGURE 1

A CONCEPTUAL MODEL OF THE INDUSTRIAL ADOPTION PROCESS
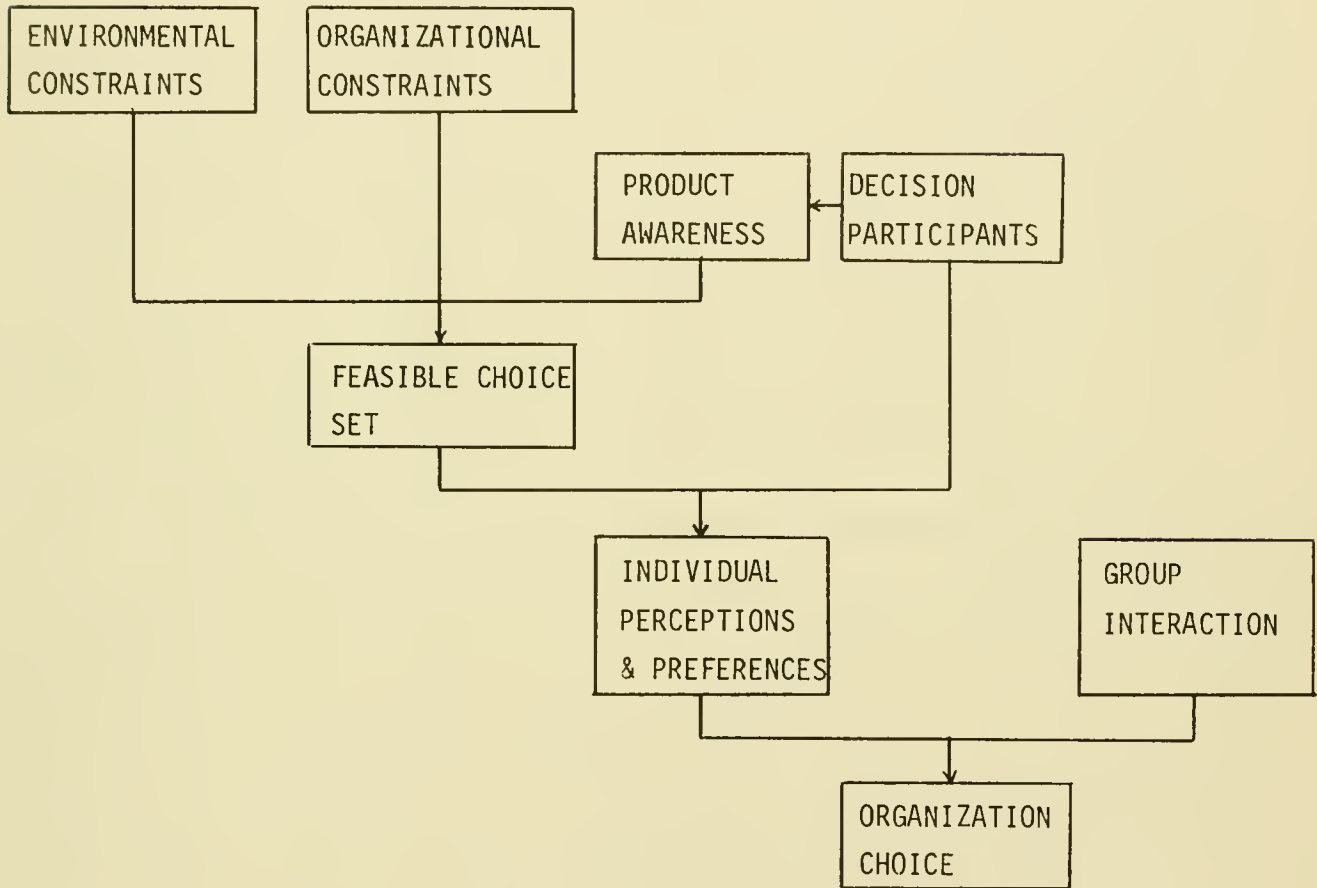
3.  The Data and Measurement Procedure

The data used for this analysis were collected as part of an EDA funded study to explore the U.S. market potential for solar powered industrial air conditioning. A sample of firms was selected by size, SIC code and geographic area and a senior management member was identified. He was sent a personal letter asking for the names of two or three members of his organization most likely to be involved in the adoption decision process for air conditioning equipment. A detailed questionnaire was then sent to the individuals mentioned. This two-step sampling procedure was used to increase the likelihood of reaching key people in the adoption decision for this class of product.

The questionnaire requested information about the company, its requirements for products in this class, its decision process and personal information. Each respondent was also exposed to three product concept statements, accurately describing the solar alternative and two conventional cooling systems. Ratings were obtained for each of these concepts on a set of perceptual scales representing relevant attributes along which decision participants assess products in this class. Seven-point Likert scales were used for this purpose. Conditional preferences for the alternatives (see Wildt and Bruno [32]) were then obtained, using both rank and constant sum methods.

A similar document was prepared and sent, via the same mail-out procedure, to HVAC (Heating, Ventilating and Air Conditioning) consulting firms. The descriptions of the products (concept statements) were identical. However, because certain issues are perceived differently and are of differential importance to outside versus inside company people, a slightly different set of attribute ratings was obtained from the consultants. Table 1 lists the scales

that are common to both groups and which were found relevant for this analysis.

The use of product descriptions or concept statements in marketing research is a widely accepted practice. Urban [29] and Hauser and Urban [13] use such concept statements to assess response to changes in the design of frequently purchased consumer products. In industrial marketing, Scott and Wright [25] recently used a similar approach to investigate the organizational buyer's product evaluation process. The approach is particularly suitable in industrial marketing as the technical complexity of product alternatives and the technical orientation of decision participants make accurate product descriptions a meaningful basis for judgement. In addition, an actual physical product is generally not available in the early stage of development of new industrial products when exploratory market research is performed.

TABLE 1:  ATTRIBUTES USED FOR AIR CONDITIONING
SYSTEM EVALUATION

1.  The system provides reliable air conditioning.

2.  Adoption of the system protects against power failures.

3.  The system is made up of field-proven components.

4.  The system conveys the image of a modern, innovative company.

5.  The system cost is acceptably low.

6.  The system protects against fuel rationing.

7.  The system allows us to do our part in reducing pollution.

8.  System components produced by several manufacturers can be substituted for one another.

9.  The system uses too many concepts that have not been fully tested.

10.  The system leads to considerable energy savings.

11.  The system is too complex.

12.  The system provides low cost a/c.

13.  The system offers a state-of-the-art solution to a/c needs.

14.  The system increases the noise level in the plant.

## 4.  Grouping of Decision Participants

In this study, likely purchase decision participants were grouped on the basis of job responsibility.  This decision is consistent with Sheth's [26] contention that product perceptions and evaluation criteria tend to differ among decision participants as a result of differences in educational background, experience, sources of information, and reference groups.  The existence of company policies that reward individuals for their specialized skills and viewpoints also tend to reinforce these psychological differences.

As some variation must be expected across companies in the responsibility corresponding to different job titles, a specific request was made in the questionnaire that the respondent describe his main job responsibility.  Five groups of respondents were then created and are used in this analysis.  We distinguish Production Engineers (PE), Corporate Engineers (CE), Plant Managers (PM), Top Managers (TM) and HVAC consultants (HC).

## 5.0 Product Perception Analysis

Each of the respondents was exposed to a concept statement describing
(1) an absorption a/c system (ABSAIR), (2) a compression a/c system (COMAIR)
and (3) the solar-powered absorption a/c system (SOLABS). (See Lilien [17]
for a technical description of these various a/c systems). Our task here is
to determine if and how the groups of decision participants -- PE, CE, PM,
TM, HC -- differ in the way they perceive these three product alternatives.

## 5.1 Perceptual Analysis Methodology

Figure 2 outlines the methodology developed for this purpose. For each
group of participants, concept ratings are obtained (A). Within each group,
concept ambiguity is tested via one-way multivariate analysis of variance (B).
Assuming that the concept statements have been carefully developed and present
an accurate description of each available alternative, the existence of am-
biguity of concept perception warns the researcher to be careful in his inter-
pretation of the preference data. Methodologies developed so far in the con-
sumer goods area have usually overlooked this problem.

For each concept statement, a multivariate profile analysis is then
performed (C), to investigate the existence of perceptual differences among
the five groups of decision participants. Tests for profile parallelism (D)
and for equality of levels (E) are applied. (See Figure 3 for an illustration
of the concept of profile parallelism and profile level equality). The
hypothesis of profile parallelism is tested by the largest characteristic root
criterion using the Heck statistic (see Morrison [22]). The hypothesis of
identical profile level is evaluated by a one-way univariate analysis of

(A) Concept Ratings for all individuals in the sample, grouped on the basis of job responsibility

(B) Test for Concept Ambiguity: One way Multivariate Analysis of variance for each group of decision participants across product alternatives

(C) Test for Perceptual Differences: Multivariate Profile Analysis for each product concept across decision participant groups.

(D) Parallel Profile?

NO → Perceptual Differences Exist

YES

(E) Profile at the Same Level?

NO → Systematic Perceptual Distortion

YES

No Perceptual Difference Across Groups of Decision Participants

(F) Univariate F-Ratios Identification of the sources of perceptual differences
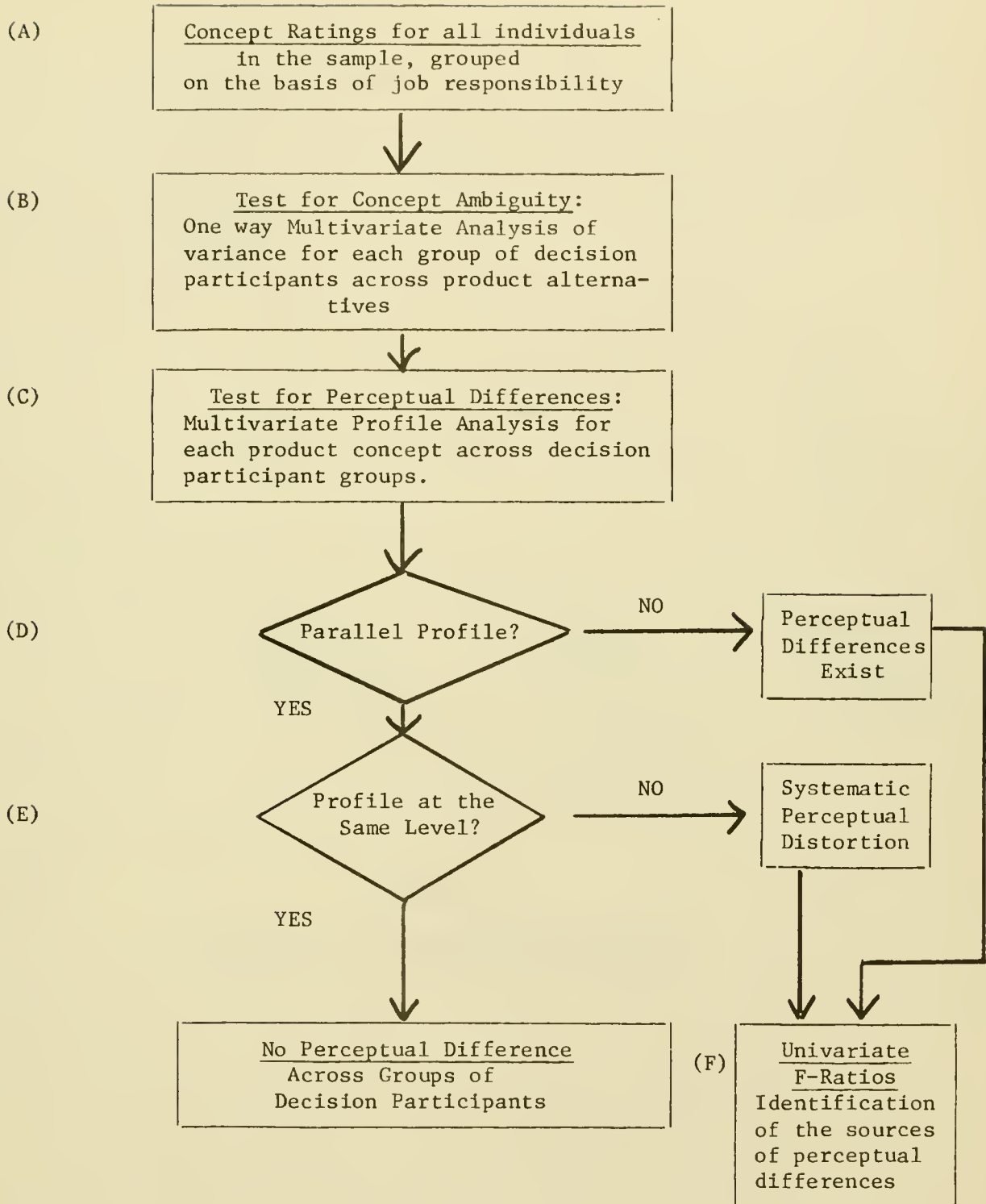
FIGURE 2

OUTLINE OF PERCEPTUAL ANALYSIS METHODOLOGY

variance on the sums of the responses of each individual across the 5 groups.
If the groups do differ in their perceptions, univariate F-ratios (F) are
obtained to isolate those basic attributes that are the major sources of
the perceptual difference.



| Item | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 |

(A) Profile          (B) Profile          (C) Non-Parallel
    Parallelism          Parallelism          Profiles

    No Perceptual        Perceptual           Perceptual
      Differences          Distortion           Differences
    ─────────────        Average Ratings
                           for Group 1
    ─ ─ ─ ─ ─ ─ ─        Average Ratings
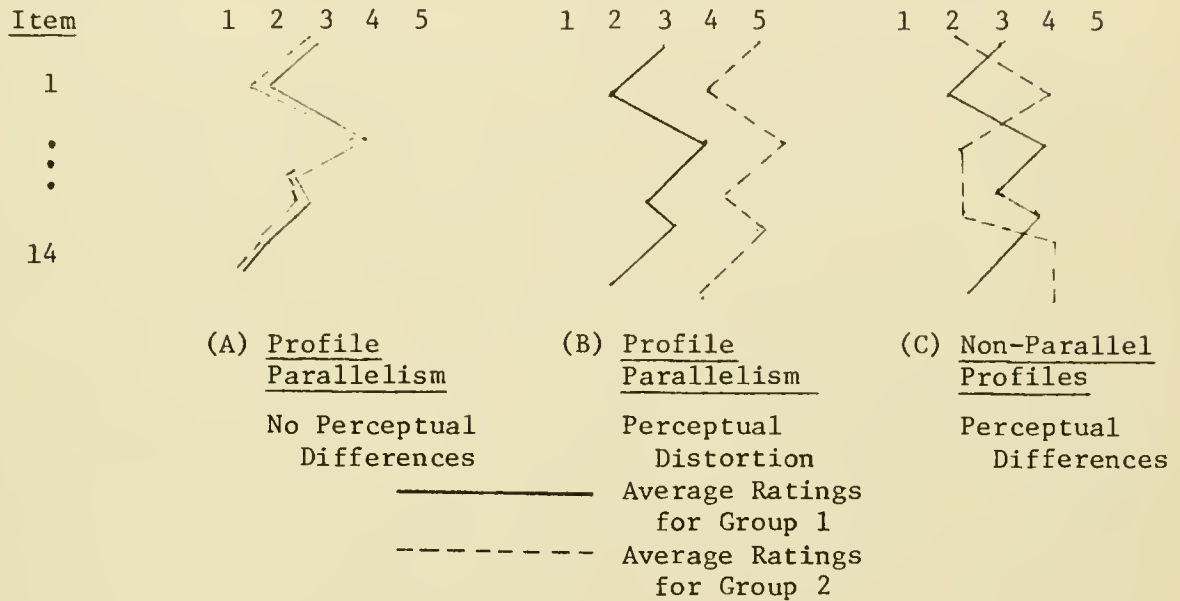                           for Group 2

FIGURE 3

THE CONCEPT OF PERCEPTUAL EQUIVALENCE

## 5.2   Perceptual Analysis Results

Application of step B of the methodology led to the conclusion that each group of likely decision participants perceived the three available alternatives as substantially different (see Choffray [ 5 ]).   This result was not unexpected as the three products indeed presented important differences.

Table 2 gives the major statistical results for the multivariate profile analysis.   Significant differences are registered between groups of decision participants in the way they perceive each product concept.   This is seen through the strong statistical significance of the Heck Criteria.

Analysis of the differences (F) via one-way univariate analysis of variance, suggests that all attributes retained in this analysis contribute to perceptual differences among at least two groups of decision participants. Table 3 presents these univariate F-ratios for PM and HC.   Plant managers (PM) view solar air conditioning (SOLABS) as a more substantial means of protection against power failures.   They also tend to consider it as more cost effective than HVAC consultants do.   Finally, plant managers view SOLABS as a complex system whose components have not been fully tested, but which provide a state-of-the-art solution to industrial air conditioning needs.   HVAC consultants' perception of SOLABS differ considerably in this last respect.

In summary, the results of this part of the analysis confirm the existence of substantial perceptual differences among the different groups of decision participants.   And the selection of the scales seemed appropriate as they all contributed to the differences noted among groups of decision participants.

TABLE 2:  MULTIVARIATE PROFILE ANALYSIS RESULTS

| Product Concept | Heck Criterion For Profile Parallelism |
|---|---|
| COMAIR | .646 * (s=4.m=4.m=98.5) |
| ABSAIR | .260 * (s=4,m=4,n=94.5) |
| SOLABS | .347 * (s=4,m=4,n=97) |

* Significant at the .01 level.

TABLE 3: COMPARISON OF GROUP MEANS FOR THE THREE PRODUCT CONCEPTS

PLANT MANAGERS VS. HVAC CONSULTANTS

| | COMAIR | | | ABSAIR | | | SOLABS | | |
|---|---|---|---|---|---|---|---|---|---|
| | PM | HC | F-RATIO (1,112) | PM | HC | F-RATIO (1,107) | PM | HC | F-RATIO (1,110) |
| ITEM 1 | 5.91 | 5.96 | .05 | 4.81 | 5.47 | 3.97** | 3.91 | 3.87 | .02 |
| ITEM 2 | 1.83 | 1.54 | 2.82* | 2.57 | 2.48 | .04 | 4.57 | 3.18 | 8.27*** |
| ITEM 3 | 5.87 | 6.10 | 1.27 | 5.14 | 5.57 | 1.86 | 3.35 | 3.25 | .08 |
| ITEM 4 | 4.30 | 3.30 | 8.85*** | 4.05 | 3.03 | 7.28*** | 5.83 | 5.70 | .15 |
| ITEM 5 | 5.09 | 5.52 | 2.90* | 3.24 | 3.22 | .00 | 2.48 | 1.89 | 3.93** |
| ITEM 6 | 3.26 | 3.25 | .00 | 2.67 | 2.19 | 1.59 | 5.78 | 5.49 | .74 |
| ITEM 7 | 3.91 | 3.67 | .37 | 3.48 | 2.55 | 6.52** | 6.04 | 5.83 | .46 |
| ITEM 8 | 4.83 | 5.12 | .71 | 3.71 | 3.84 | .08 | 3.61 | 4.17 | 1.80 |
| ITEM 9 | 2.35 | 1.79 | 3.79* | 2.95 | 2.34 | 2.88* | 4.74 | 4.08 | 2.83* |
| ITEM 10 | 2.65 | 3.18 | 2.82* | 3.19 | 2.56 | 2.93* | 5.70 | 6.10 | 2.25 |
| ITEM 11 | 3.04 | 2.12 | 11.78*** | 3.62 | 2.97 | 2.91* | 3.61 | 3.57 | .01 |
| ITEM 12 | 3.26 | 4.54 | 18.34*** | 3.33 | 3.16 | .21 | 4.96 | 4.21 | 3.10* |
| ITEM 13 | 4.35 | 4.64 | .72 | 3.57 | 3.85 | .55 | 5.52 | 4.56 | 6.44** |
| ITEM 14 | 4.96 | 4.82 | .15 | 2.57 | 2.05 | 2.87* | 1.83 | 2.08 | .73 |

* Significant at .10 level      ** Significant at .05 level      *** Significant at .01 level

## 6.0 Product Evaluation Space Analysis

Although individuals can accurately describe their perceptions of product alternatives on a set of perceptual scales, it is unlikely that they consider all these attributes independently in a choice situation (see Miller [20]). Several basic attrinutes of the product class under investigation may be interrelated because they comprise the same underlying evaluation criteria (Howard and Sheth [14]).

In this part of the analysis, we are concerned with the evaluation criteria that each group of potential decision participants uses assuming that all individuals within a given group use the same evaluation criteria. An individual's evaluation of a product alternative may then be seen as a vector or coordinates in this reduced product evaluation space (Howard and Sheth [14]; Allaire [1]; Hauser [12]).

Two questions arise immediately:

- Is the dimensionality of the evaluation spaces (that is, the number of evaluation criteria) the same for the different groups of potential decision participants?

- If so, are the evaluation criteria essentially equivalent?

The methodolcgy outlined below addresses both these issues.

## 6.1 Product Evaluation Space Methodology

Figure 4 outlines the steps in the evaluation space analysis. Concept ratings are obtained for each concept statements (A). Then, variance-covariance matrices are calculated for each group of decision participant across concepts (B). This approach was suggested by Urban [29] as a way to increase the number of degrees of freedom in the derivation of the evaluation
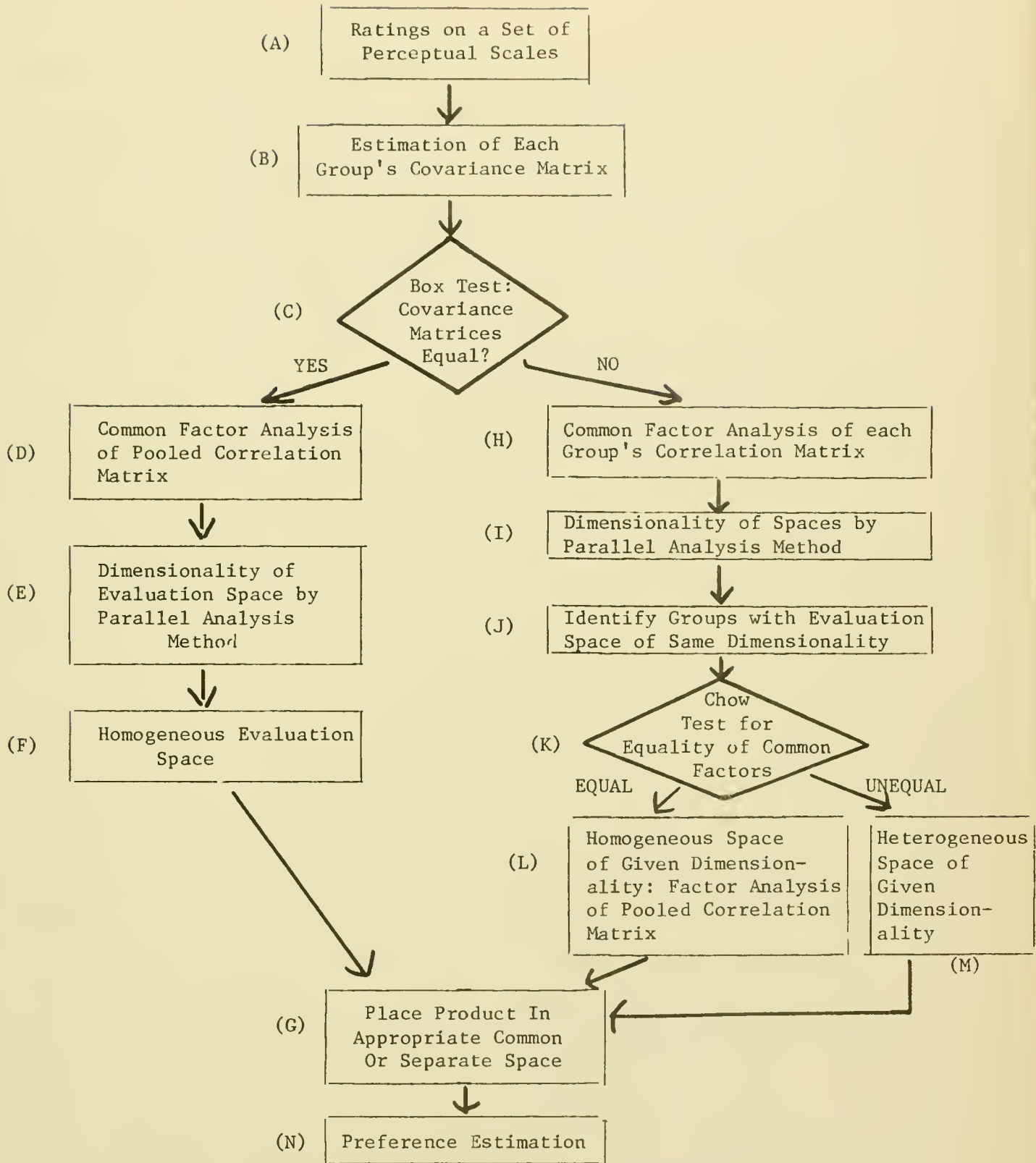
FIGURE 4:  OUTLINE OF EVALUATION SPACE METHODOLOGY

space. It is intuitively appealing, as it implies that for each group all products in the product class are assessed along the same set of evaluation criteria. Box's [2] test is then used to test the equality of these variance-covariance matrices (C). If the matrices are found to be equal they are pooled, factor analyzed and product alternatives as perceived by each individual are placed in the common evaluation space (D,E,F,G).

Box's test is very powerful, however (Greenstreet and Connor [9], Cooley and Lohnes [7]). Rejection of the hypothesis of equality of groups' variance-covariance matrices should only be taken as an indicator of possible differences in the evaluation spaces of each group. Indeed, as common factor analysis does _not_ make use of all information present in these matrices, it is possible that the evaluation spaces are similar even though the hypotheses of equality of covariance matrix is rejected.

If the hypothesis of equal variance-covariance matrices is rejected, separate factor analyses are performed for each group (H). The parallel analysis technique (Humphreys and Ilgen [15]) is then used to determine the dimensionality of the evaluation space of each group of decision participants. The method involves the factoring of a second correlation matrix identical in the number of variables and observations as the original data matrix, but obtained from randomly generated normal deviates. Recently, Montanelli and Humphreys [21] provided a method of estimating the expected values of the latent roots of random data correlation matrices with squared multiple correlations on the diagonal. This method was used here.

Inequality of dimensionality indicates the existence of a substantial difference in the evaluation space (I). Otherwise, groups of decision participants that present an identical number of evaluation criteria are further tested for

equality of these criteria using a modified version of Chow's test [ 6 ] (see Appendix 1 for a description of the test) (K). If the evaluation criteria are deemed similar, the concept ratings for these groups are pooled and factor analysis is performed again to determine the evaluation space common to these groups (L). For each individual, product coordinates in the appropriate evaluation space are then assessed (G).

The final step of the methodology is preference estimation (N). Once products are positioned in the appropriate evaluation space, individual preferences for the available alternatives can be linked to the products' coordinates in this space. This step of the methodology then assesses the relative importance of the evaluation criteria in the formation of preferences within decision participant groups.

6.2  Product Evaluation Space Results

Individual covariance matrices were estimated for each of the five groups (HC, PE, CE, PM and TM) using ratings obtained on the 14 perceptual scales. The Box Test was used to test the equality of these covariance matrices, giving an F-ratio of 1.80 for 408 and 226,827 degrees of freedom. The hypothesis of equal covariance matrices was then rejected and a separate principal factor analysis was performed for each group. Squared multiple correlations were used as estimates of the communalities of the original perceptual scales, and were computed within each group.

The dimensionality of each group's evaluation space was obtained by the parallel analysis method. Figure 5 presents the observed trace of eigenvalues and the zero information trace for production engineers (PE). The point at which the curves cross indicates the number of factors that should be retained.
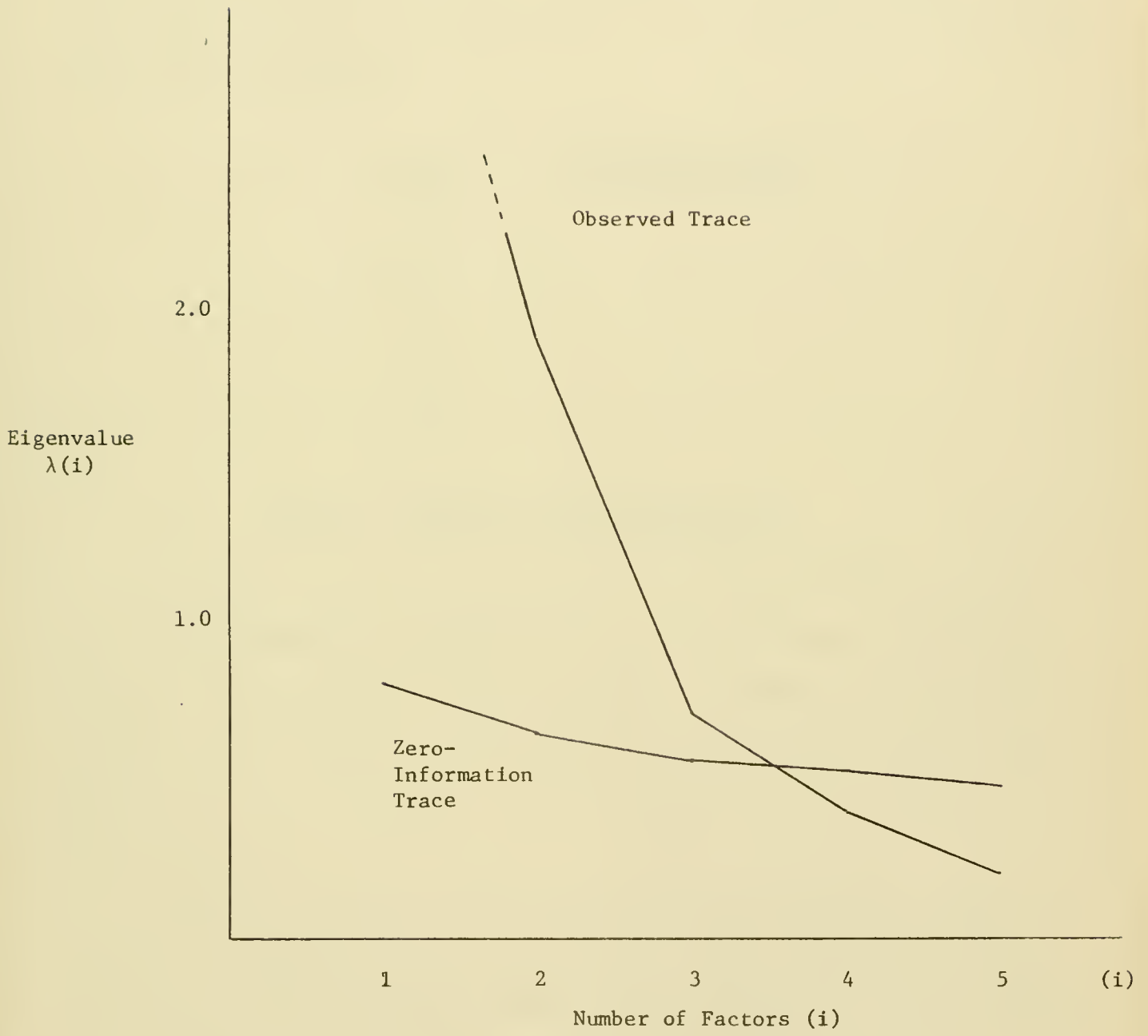
FIGURE 5: DETERMINATION OF DIMENSIONALITY OF EVALUATION SPACE
FOR PRODUCTION ENGINEERS (PE)

We are not interested in a factor that does not account for more variance than the corresponding factor obtained from distributions of random numbers. The dimensionality of the PE evaluation space is then 3. The results for the other groups are given in Table 3.

| GROUP | DIMENSIONALITY OF EVALUATION SPACE |
|-------|-----------------------------------|
| CE | 2 |
| PM | 2 |
| PE | 3 |
| TM | 3 |
| HC | 3 |

TABLE 3:   EVALUATION SPACE DIMENSIONALITY

Two groups have an evaluation space of dimensionality 2 (CE and PM) and the other three groups (PE, TM, HC) have a three-dimensional evaluation space. This indicates that Production Engineers, Top Managers, and HVAC consultants who have relatively more responsibility in the decision process (see Cheston and Doucet [ 3 ]) appear to use more decision criteria. We treat the CE-PM groups first.

Separate common factor analyses were run for CE and PM and a varimax rotation was performed on each (see Appendix 2). Most similar factors were identified and their equivalence tested one at a time using a modified version of the Chow Test, as indicated in Appendix 1. Table 4 gives the results.

|  | F-Ratio | Degrees of Freedom |  |
|---|---|---|---|
| A. Matched factors ($PM_1$, $CE_2$) | 1.84 | 14,125 | * |
| B. Matched factors ($PM_2$. $CE_1$) | 1.48 | 14,125 | |

(Note: $PM_i$ represents the ith factor in the original varimax solution for PM).

* Significant at the .05 level.

### TABLE 4: TEST OF FACTOR EQUALITY FOR PM AND CE

As Factor A is significantly different for the two groups (and Factor B is nearly so), we reject the hypothesis of equality of evaluation criteria for these two groups.

Similarly, PE, TM and HC's have an evaluation space of dimensionality 3. Table 5 tests factor equivalence for these groups.

|  | F-Ratio | Degrees of Freedom |  |
|---|---|---|---|
| A. Matched Factors ($PE_1$, $TM_1$, $HC_1$) | 1.80 | 14,459 | * |
| B. Matched Factors ($PE_2$, $TM_2$, $HC_2$) | 1.91 | 14,459 | * |
| C. Matched Factors ($PE_3$, $TM_3$, $HC_3$) | 21.8 | 14,459 | ** |

* Significant at .05 level

** Significant at .001 level

### TABLE 5: TEST OF FACTOR EQUALITY FOR PE, TM AND HC

Thus, these groups exhibit substantial differences in their evaluation criteria and should be analyzed separately. The interpretation of these evaluation criteria leads to interesting qualitative distinctions between decision participant groups. For the two factor solutions we summarize and interpret the results in Table 6.

|                          | Factor A            | Factor B                      |
|--------------------------|---------------------|-------------------------------|
| Corporate Engineer (CE)  | Reliability/        | Pollution                     |
|                          | Field Tested        | Energy Savings/Protection     |
|                          | First Cost          | Modernness                    |
|                          | Noise Level         |                               |
|                          |                     |                               |
| Plant Manager (PM)       | Energy Savings/     | Reliability/ Field Tested     |
|                          | Protection          | Modularity                    |
|                          | Modernness          | Noise Level                   |
|                          | Low Operating Cost  |                               |

TABLE 6:  COMPARISON OF FACTOR SOLUTIONS FOR CE, PM

The issue of air condition systems' initial costs does not appear to
be vital to Plant Managers; modernness, energy savings and protection against
fuel rationing and power failures are primary.  On the other hand, corporate
engineers see the system's reliability and first costs as the primary issues.

Similarly, Table 7 presents an interpretation of the factor solutions
for the other three groups, TM, PE and HC.  The composition of the first factor
indicates minor differences between these groups in terms of their first
evaluation criteria (TM include  protection against power failures and HC do
not place the same emphasis on low operating cost).  Major differences, however,
arise in the second and third factors.  Production Engineers (PE) emphasize
system complexity and modularity more than other groups.  First cost comes
out clearly as an important element in top managers' (TM) evaluation of
industrial a/c equipment.

| | Factor A | Factor B | Factor C |
|---|---|---|---|
| Production Engineer (PE) | Energy Savings/ Protection<br>Low Operating Cost<br>Modernness | Modularity<br>Noise Level | Complexity<br>Field Tested |
| Top Manager (TM) | Energy Savings/ Protection<br>Low Operating Cost<br>Modernness<br>Protection against Power Failure | Reliability/ Field Tested<br>Initial Cost | Noise Level |
| HVAC Consultant (HC) | Energy Savings/ Protection<br>Modernness | Reliability/ Field Tested | Noise Level<br>Initial Cost |

TABLE 7:  COMPARISON OF FACTOR STRUCTURES
FOR PE, TM AND HC

In sum, our analysis of the evaluation space for each group suggests
that they not only differ in the number of evaluation criteria but, that
substantial variation appears in the composition of those criteria.  Dif-
ferent marketing strategies, including product positioning and salesmen pre-
sentations, can be targeted at these different groups to take advantage of
these differences.

The next question is whether the evaluation analysis, performed at such
a disaggregate level is behaviorally meaningful:  does the consideration of
these specific, and different evaluation criteria lead to a better understand-
ing of the way decision participants form preferences?

The link between individuals' preferences for the three alternatives and
their evaluation of these alternatives along the appropriate evaluation criteria
is investigated using a linear model, where we refer to the estimated coeffi-
cients as preference parameters.  The analysis is performed under three dif-
ferent sets of assumptions:

A1: The evaluation criteria are the same across decision participant groups as are preference parameters.

A2: The evaluation criteria are the same across groups but preference parameters differ.

A3: Both the evaluation criteria and the preference parameters differ across groups.

The two measures of preference requested in the questionnaire -- ranks and constant sum paired comparisons -- were used to eliminate individuals inconsistent in their preference judgements. Although not statistically significant, our results indicate that corporate people (TM, CE) are less consistent in their preference judgements than people working at the plant level (PM, PE).

Two sets of regression were run. First, the actual rank-order was used as a dependent variable with the estimated factor scores as independent variables. Although our dependent variable is only ordinal, available empirical evidence suggests that least square regressions closely approximate monotonic regression for integer rank order preference variables (Green [10], Hauser and Urban [13]). Second, the constant sum paired comparison preference data were transformed to a ratio scale via Torgerson's [27] method, and used as a dependent variable.

Preference recoveries (for both first preferences and the actual rank order of each individual's preferences) are sensible goodness of fit measures for preference regressions and have been extensively reported in the literature (Hauser and Urban [13], Wildt and Bruno [3]). With three alternatives, a random model would recover first preference 1/3 of the time and give total preference recovery 1/6 of the time.

Table 8 summarizes the preference recovery results under all three sets of assumptions. It appears that average preference recovery (when both rank and ratio scaled preference recovery results are averaged) is best when heterogeneity

of evaluation criteria and preference parameters is considered (Assumption A3).

An unexpected result is that the average preference recovery is somewhat

superior under assumption A1 (that is homogeneous evaluation criteria and homo-

geneous preference parameters) than under assumption A2 (homogeneous evaluation

criteria and heterogeneous preference parameters).  This finding indicates

that although A2 is a reasonable assumption in consumer marketing research

(Allaire [ 1 ], Hauser [12]) it might not be reasonable in industrial markets,

where different groups of decision participants exhibit substantial diver-

gence in their perceptions of product alternatives and in their evaluation

criteria.

| | A1 Homogeneous Evaluation Criteria Homogeneous Preference Parameters | A2 Homogeneous Evaluation Criteria Heterogeneous Preference Parameters | A3 Heterogeneous Evaluation Criteria Heterogeneous Preference Parameters |
|---|---|---|---|
| 1st Preference Recovery | .67 | .65 | .72 |
| All Preference Recovery | .44 | .41 | .52 |

TABLE 8:   AVERAGE PREFERENCE RECOVERY

Table 9 gives the results for the rank-regression under assumption A3 for all

five groups.  Similar results were obtained by the use of ratio-scaled prefer-

ences and are reported by Choffray [ 4 ].

The results listed in Table 9 suggest interesting differences in the

way product evaluations are related to individual preferences within each group.

First, consider Corporate Engineers and Plant Managers (Table 6 interprets

their evaluation criteria).  Corporate Engineers find reliability and first

cost most important while Plant Managers find modernness, fuel savings and
low operating costs to be most significant.

| Group | Constant | Regression Coefficients 1st Factor | Regression Coefficients 2nd Factor | Regression Coefficients 3rd Factor | No. of Observations |
|-------|----------|------------------------------------|------------------------------------|------------------------------------|---------------------|
| CE | 2.02 | -.46 | -.10 | x | 115 |
| PM | 2.00 | -.25 | -.19 | x | 84 |
| PE | 1.99 | -.39 | .27 | (.09)* | 66 |
| TM | 1.99 | -.37 | -.18 | -.13 | 123 |
| HC | 1.99 | (-.02)* | -.31 | -.45 | 273 |

* not significantly different from 0 at the .10 level.

TABLE 9:   RANK-PREFERENCE REGRESSION COEFFICIENTS UNDER A3

The comparison of the other three groups is most interesting.  Production
Engineers find modernness, low operating cost and protection against fuel ra-
tioning most important.  But they seem to favor more complex, less noisy and
potentially more risky alternatives  (seen from the positive sign of that
regression coefficient).  Production Engineers are perhaps the only individuals
in the decision process who will work with this equipment directly and, seem
to favor that equipment which makes their job more challenging.  Top managers
also find modernness, protection and low operation cost most important, but
weight reliability and initial cost heavily as well, in the expected direction.
Finally, HVAC consultants do not seem concerned about modern image, low
operating cost, and fuel rationing protection.  Their concerns are immediate --
they weight initial cost and noise level most heavily and, secondarily
reliability and the presence of field proven components.

Hence, each of these groups not only evaluates the various alternatives differently, but the nature of the link between products evaluations and individual preferences is different as well. It is important to note that the preference regressions run under A2 -- common evaluation space and heterogeneous preference parameters (not reported here) -- suggested neither the positive association with system complexity noted above for Production Engineers (PE), nor the absence of association with modernness, low operating cost and fuel rationing protection for HVAC consultants (HC). The use of this new methodology is, then, a necessary step in the identification of these important psychological differences among decision groups.

## 7.0 Marketing Implications

The previous sections suggested important differences in the way various groups of decision participants perceive and evaluate industrial air conditioning systems. A well-integrated marketing and R&D program will tap these differences in both a product design and a marketing communications program.

Table 9 summarizes the differences between these groups.

| | Issues of Key Importance | Issues of Less Importance |
|---|---|---|
| Production Engineer (PE) | modernness<br>protection against fuel rationing<br>complexity | first cost |
| Corporate Engineer (CE) | reliability<br>first cost | modernness of image<br>energy savings |
| Plant Manager (PM) | protection against fuel rationing<br>modernness<br>low operating cost | first cost |
| Top Manager (TM) | protection against fuel rationing<br>modernness<br>low operating cost | noise level in plant<br>ease of component replacement |
| HVAC Consultant (HC) | noise level in plant<br>first cost<br>reliability | modernness<br>low operating cost |

TABLE 10: IMPORTANCE OF ISSUES TO DIFFERENT GROUPS OF DECISION PARTICIPANTS

The table suggests that, when communicating to Top managers and Plant Managers, low operating and initial costs must be stressed, along with modernness of company image and protection against fuel rationing. When promoting the new product to an HVAC consultant, however, first costs, reliability and low noise level should be emphasized.

Referring back to Table 3, it appears that HVAC consultants perceive SOLABS to be considerably less reliable than the other two systems. The preference analysis indicates this to be a key item affecting HVAC system preference. Thus, this information isolates areas in need of engineering improvement and determines what messages a communication program might target at a particular group.

The key contributions of the new methodology of importance to the introduction of solar a/c (and to industrial marketers in general) fall under two categories:

A. Differences in Product Perception:

- Identification of characteristics of the new system which are not perceived by some group as management would like, so that corrective action can be taken.

- Development of advertising copy which accounts for the specific needs and requirements of each group of decision participants.

B. Evaluation Criteria Differences

- Identification of areas of potential weaknesses in design and positioning by assessing the new product's position in the evaluation space relative to that of competitors.

- Development of salesmen's presentations and salesforce strategies that account for the specific needs of the different decision participants.

- Development of communication programs directed at particular groups of participants, making use of their specific sources of information.

## 8.0 Conclusions and Implications for Research

The key implications of this work for the marketing of new industrial products are that:

- the way industrial products are <u>perceived</u> by different groups of decision participants differ substantially, and that

- the <u>evaluation criteria</u>, along which decision participants assess product alternatives, differ from one group to another.

An important result of this analysis is that differences in product perception and evaluation criteria among different groups involved in the adoption of a new industrial product must be explicitly included in an analysis of individual preferences.

Choffray and Lilien [5] have outlined how this information can be used in an industrial market response model. Their procedure first requires the identification of the target market for the new industrial product (called macrosegmentation). Organizations' selection criteria are then measured along with the structure of their adoption processes. This information is used to form microsegments of the potential market, in which companies exhibit a similar pattern of adoption process involvement. Individual preferences are then investigated for each relevant group of decision participants, and individual choice models are calibrated. An estimate of the expected market share for the new product can then be obtained under various assumptions about the type of interaction occurring in each microsegment.

The work reported in this paper is then part of a research plan aimed at developing better tools for analyzing industrial markets. Here, we stressed the analysis of the process of perception evaluation and preference for different actors in the industrial adoption process. This field of research is in need of better models and measurement tools. The results here indicate that potential for improvement exists.

APPENDIX 1

USE OF THE CHOW TEST IN
ESTABLISHING EQUALITY OF SEVERAL FACTORS
OBTAINED FROM THE SAME SET OF VARIABLES IN DIFFERENT SAMPLES

A1.   The Chow Test:   Consider two regression models:

(1)   $Y_1 = X_1 \beta_1 + \varepsilon_1$

(2)   $Y_2 = X_2 \beta_2 + \varepsilon_2$

where $Y_i$ is $(n_i \times 1)$, $X_i$ is $(n_i \times m)$, $\beta_1$ and $\beta_2$ are vectors of coefficients and $\varepsilon_1$, $\varepsilon_2$ are vectors of disturbances.  The null hypothesis, $\beta_1 = \beta_2$ gives rise to the reduced model:

(3)   $Y = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \beta + \varepsilon$

If we let $e_1$, $e_2$ and $e$ be residual vectors associated with least squares estimation of (1), (2) and (3), respectively, then Chow [  ] shows that, under the null hypotheses,

(4)   $C = \left\{ \dfrac{e'e}{e_1' e_1 + e_2' e_2} - 1 \right\} \dfrac{N-2m}{m}$

is distributed as F with m, (N-2m) d.f.  (where $N = n_1 + n_2$).

A2.   Application to the Comparison of Factors Obtained in Different Samples

The common factor analysis model expresses each observed variable $\{z_j, j=1,\ldots q\}$ as a linear combination of a small number of common factors

$\{F_p,\ p=1,\ldots m\}$ with $m \leq q$ plus a unique factor $U_j$.

$$(5) \quad z_{ji} = \sum_{p=1}^{m} a_{jp} F_{pi} + k_j U_{ji} \quad ,$$

where $a_{jp}$ and $k_j$ are the factor pattern coefficients, and

subscript i refers to a particular individual in the sample

$(i=1,\ldots n)$.

The factors $F_p$, $p=1,\ldots m$ , however, are hypothetical <u>unobserved</u>

constructs. In the case of most common factor analysis techniques, the fac-

tor scores have to be estimated indirectly. Linear regression on the ori-

ginal variables $z_j$, $j=1,\ldots q]$ is often used for this purpose (Harman [11]).

The model may be expressed as follows:

$$(4) \quad F_{pi} = \sum_{j=1}^{q} \beta_{pj} \cdot z_{ji} + \varepsilon_{pi}$$

where $\beta_{pj}$ is the regression coefficient of factor $F_p$ on variable $z_j$.

When the common factors are orthogonal, Harman [11] shows that $R_p$,

the coefficient of multiple correlation associated with the estimation of

factor $F_p$, can be calculated as

$$(5) \quad R^2_p = \sum_{j=1}^{q} b_{pj} s_{jp}$$

where the $b_{pj}$'s are least squares estimates of the $\beta_{pj}$'s and

$\{s_{jp},\ j=1,\ldots q;\ p=1\ldots m\}$, are the correlations between the original

variable $z_j$'s and the factor $F_p$'s.

Under the usual assumptions of the common factor analysis model, it can be shown (Choffray [5]) that:

$$(6) \quad \sum_{i=1}^{n} (F_{pi} - \hat{F}_{pi})^2 \;=\; n(1-R_p^2)$$

We can then use (6) in (4), as $\sum_{i=1}^{n} (F_{pi} - \hat{F}_{pi})^2$ is the sum of the squared residuals $e'_p \, e_p$ associated with the estimation of the factor scores $F_p$.

Hence, the statistic

$$(7) \quad C_p \;=\; \frac{N(1-R_p^2)}{n_1(1-R_{p1}^2) + n_2(1-R_{p2}^2)} - 1 \quad \frac{N-2q}{q}$$

can be used to test the equality of a specific factor obtained from the same set of variables in two different samples, where

$R_{p1}^2 \, , \; R_{p2}^2$ are the squared multiple correlations associated with the estimation of factor p in sample 1 and 2 respectively,

$R_p^2$ is the squared multiple correlation associated with factor p in the pooled sample, and

$N \qquad = n_1 + n_2$

The test is readily extendable to the case where more than two samples are included in the analysis.

APPENDIX 2

ROTATED FACTOR LOADING MATRICES FOR THE FIVE GROUPS*

(*Note:  See Table 1 for complete description of items.)

TABLE 11:   VARIMAX ROTATED FACTOR MATRIX FOR PE

|         | FACTOR 1 | FACTOR 2 | FACTOR 3 |
|---------|----------|----------|----------|
| Item 1  | -0.22316 | 0.42747  | -0.56334 |
| Item 2  | 0.46540  | -0.39623 | 0.07877  |
| Item 3  | -0.25144 | 0.66075  | -0.58387 |
| Item 4  | 0.65962  | -0.26155 | 0.03730  |
| Item 5  | -0.02264 | 0.47154  | -0.35798 |
| Item 6  | 0.75290  | -0.00082 | 0.30641  |
| Item 7  | 0.76803  | -0.02595 | 0.29846  |
| Item 8  | 0.02738  | 0.60433  | -0.04732 |
| Item 9  | 0.35929  | -0.32116 | 0.70671  |
| Item 10 | 0.75243  | -0.24124 | 0.26847  |
| Item 11 | -0.07375 | -0.03003 | 0.62834  |
| Item 12 | 0.76282  | 0.09390  | -0.04418 |
| Item 13 | 0.61089  | -0.05849 | -0.15229 |
| Item 14 | -0.10680 | 0.61909  | -0.10051 |

Percentage of the common variance reproduced by the
3 factors:   87%

TABLE 12:   VARIMAX ROTATED FACTOR MATRIX FOR TM

|         | FACTOR 1 | FACTOR 2 | FACTOR 3 |
|---------|----------|----------|----------|
| Item 1  | -0.09834 | 0.70547  | 0.07601  |
| Item 2  | 0.61259  | -0.29941 | -0.19113 |
| Item 3  | -0.30730 | 0.77046  | 0.31167  |
| Item 4  | 0.65816  | -0.05916 | -0.07040 |
| Item 5  | 0.07488  | 0.55076  | 0.46701  |
| Item 6  | 0.81028  | -0.20987 | -0.08010 |
| Item 7  | 0.81101  | -0.25434 | -0.02270 |
| Item 8  | -0.13723 | 0.38997  | 0.18660  |
| Item 9  | 0.26682  | -0.74154 | -0.20041 |
| Item 10 | 0.70086  | -0.31026 | -0.11608 |
| Item 11 | -0.17011 | -0.59742 | 0.10276  |
| Item 12 | 0.71900  | 0.12102  | 0.04088  |
| Item 13 | 0.54980  | 0.19404  | 0.06809  |
| Item 14 | -0.07618 | 0.20695  | 0.97375  |

Percentage of the common variance reproduced by the
3 factors:   90%

TABLE 13:    VARIMAX ROTATED FACTOR MATRIX FOR CE

|         | Factor 1  | Factor 2  |
|---------|-----------|-----------|
| Item 1  | 0.71613   | -0.17387  |
| Item 2  | -0.35160  | 0.14687   |
| Item 3  | 0.80057   | -0.31993  |
| Item 4  | -0.15252  | 0.61189   |
| Item 5  | 0.76775   | 0.01970   |
| Item 6  | -0.01547  | 0.76712   |
| Item 7  | -0.24906  | 0.80415   |
| Item 8  | 0.40947   | 0.18330   |
| Item 9  | -0.81782  | 0.41061   |
| Item 10 | -0.32790  | 0.69898   |
| Item 11 | -0.48200  | 0.11139   |
| Item 12 | -0.06724  | 0.46189   |
| Item 13 | 0.17781   | 0.44631   |
| Item 14 | 0.55548   | 0.05201   |

Percentage of the common variance
reproduced by the 2 factors:   83%

TABLE 14:    VARIMAX ROTATED FACTOR MATRIX FOR PM

|         | Factor 1  | Factor 2  |
|---------|-----------|-----------|
| Item 1  | -0.06350  | 0.79864   |
| Item 2  | 0.51733   | -0.36001  |
| Item 3  | -0.34726  | 0.83285   |
| Item 4  | 0.58111   | 0.05618   |
| Item 5  | -0.23362  | 0.38299   |
| Item 6  | 0.78108   | -0.25548  |
| Item 7  | 0.67658   | -0.25569  |
| Item 8  | 0.07472   | 0.61947   |
| Item 9  | 0.26725   | -0.71792  |
| Item 10 | 0.82866   | -0.23721  |
| Item 11 | -0.18898  | -0.44761  |
| Item 12 | 0.74933   | 0.08457   |
| Item 13 | 0.59198   | -0.02587  |
| Item 14 | -0.34224  | 0.50309   |

Percentage of the common variance
reproduced by the 2 factors:   90%

TABLE 15:   VARIMAX ROTATED FACTOR MATRIX FOR HC

|  | FACTOR 1 | FACTOR 2 | FACTOR 3 |
|---|---|---|---|
| Item 1 | -0.01453 | 0.77400 | 0.16627 |
| Item 2 | 0.32379 | -0.13874 | -0.31433 |
| Item 3 | -0.16840 | 0.88049 | 0.20698 |
| Item 4 | 0.76014 | -0.16269 | -0.25089 |
| Item 5 | -0.04686 | 0.53063 | 0.66995 |
| Item 6 | 0.62641 | -0.32135 | -0.10489 |
| Item 7 | 0.71850 | -0.30453 | -0.10532 |
| Item 8 | 0.28045 | 0.27643 | 0.29778 |
| Item 9 | 0.20946 | -0.54396 | -0.21152 |
| Item 10 | 0.71165 | -0.34161 | -0.13029 |
| Item 11 | 0.09245 | -0.35529 | -0.25870 |
| Item 12 | 0.49252 | 0.17796 | 0.25933 |
| Item 13 | 0.52640 | 0.23294 | 0.13880 |
| Item 14 | -0.03456 | 0.13695 | 0.59170 |

Percentage of the common variance reproduced by
the three factors:   94%

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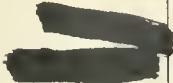
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