MANAGEMENT DECISIONS FOR COGENERATION:
EXECUTIVE SUMMARY

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Dr. Richard D. Tabors

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ABSTRACT
MANAGEMENT DECISIONS FOR COGENERATION:
EXECUTIVE SUMMARY
BY
ROBERT R. RADCLIFFE
DR. RICHARD D. TABORS

This report summarizes two interdependent studies which explore the underlying factors in the decision by private, private non-profit, and public sector facility owners to invest in cogeneration technology. They employ factor analysis techniques to explain the decision to invest and discriminant analysis to group the survey respondents into non-cogenerators and potential cogenerators. Data for both studies come from a survey of commercial, industrial, and institutional electric energy consumers who used more than 750 KW demand in any one month of 1981 for a selected electric utility in the Boston area. There were 129 usable responses to the survey or 32.2 percent of the population.

Cogeneration is the sequential production of thermal energy and electricity at one facility. A technology advocated for its high thermodynamic efficiency compared to separate production of steam and electricity, cogeneration represents an opportunity for a facility owner to substitute capital expenditure today for future operating expenditures. For the past six years, projections of increased cogeneration of electricity and steam consistently occurred in the literature. Over the same period output of steam and electricity from cogeneration plants has declined. In the face of contradictions between thermodynamic efficiency based projections of cogeneration potential and the reality of declining actual use, most reports offer anecdotal references to market imperfections and non-economic decision variables to justify the contradiction.

First, the studies reported here confirm that a number of factors other than purely economic considerations may prevent use of cogeneration technology at the present time. These factors include:
Uncertainty caused by regulatory action
Desire for energy self sufficiency by the organization
Financial flexibility
Experience with electricity cogeneration or self generation
Capital budget planning methods

Second, these studies provide a ranking of the factors involved in the cogeneration decision explaining most variance to least variance. However, the ranking of factors provides no measure of the "importance" of these factors in the decision to adopt or not adopt cogeneration technology.

Finally, the results of these studies can be used to provide a rough estimate of capacity (KW) and energy (KWH) available from potential cogenerators in this electric utility service territory and the probability that a facility can be a cogenerator. These studies project a maximum potential of 106 MW and 559,000 MWH of cogenerated electrical energy in the utility service territory between 1982 and 2002.
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CHAPTER 1
COGENERATION DECISIONS
INTRODUCTION

1.1 Introduction and Conclusions

This summary combines the results of two technical papers on
Management Decisions for Cogeneration. The two major conclusions of
these studies are:

1) The potential for cogeneration of electricity and steam in the
evaluated electric utility is small.
   Study results demonstrate a maximum potential over the next
   20 years for this utility of 106 Megawatts capacity. At an
   estimated capacity factor of 60 percent, this translates into
   a maximum annual potential of 559,000 Megawatt hours of
   energy.

2) The leverage an electric utility firm has upon private,
   private non profit, or public sector cogeneration decisions is small.
   Study results confirm that a number of non economic factors
   over which the utility has little if any influence have an
   affect upon the decision of organizations to adopt
cogeneration technology. These factors are listed below.
**INFERRED FACTORS IN THE DECISION TO COGENERATE**

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>1</td>
<td>Cost Uncertainty Due to Regulation</td>
</tr>
<tr>
<td>2</td>
<td>Desire for Energy Self Sufficiency</td>
</tr>
<tr>
<td>3</td>
<td>Present Cogenerator</td>
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<td>4</td>
<td>Significant Corporate Energy Conservation Objectives</td>
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<td>5</td>
<td>Corporate Financial Flexibility</td>
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<td>6</td>
<td>Willingness to Enter Joint Ventures with Utility</td>
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<td>7</td>
<td>Utility Physical constraint - water and electric availability</td>
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<td>9</td>
<td>Cost of Capital</td>
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<td>Timing of investment relative to business cycles</td>
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<td>Corporate Investment Policy</td>
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<tr>
<td>12</td>
<td>Corporate Planning Methods</td>
</tr>
</tbody>
</table>

Since the electric utility has little or no leverage to affect factors 1 to 4 or factors 8 to 12, there is a strong indication that the utility cannot easily positively affect the decision to adopt cogeneration technology short of joint financial ventures (factors 5 and 6). We make several assumptions in these two analyses which have an effect on our conclusions. They are:

1) The most cost effective cogeneration systems in the northeast are or would be coal fired.

2) Oil fired cogeneration steam systems may be sized to meet base load and may be cost effective as long as the electric utility uses oil as its marginal generation fuel.

3) High speed diesels will not be cost effective on this utility system due to the fact that the utility marginal fuel is less expensive number 6 oil.

4) Low speed diesels will have major difficulties meeting air quality control laws in the urban areas of Boston.
The reader is cautioned not to make sweeping generalizations of these results or assumptions to other utility territories. In particular, relative prices of electric energy, electric demand, and fuel used for electric generation vary substantially between utilities. Relative price differences may be due to differences in taxation, in energy demand charges, in use of ratchet charges, or a combination of the three.

1.2 MEASUREMENT GOALS

This report drew upon disciplines other than engineering economics to identify variables in the decision process for investment in cogeneration systems. Our hypothesis was that the nature of the investment decision process used by private, private non-profit, and public organizations limited the potential penetration of cogeneration technologies in the Northeast United States.

These studies sought to answer the following questions:

1) Are non-economic variables important in the decision to use cogeneration technology?

2) If non-economic variables are important in the decision to use cogeneration, which variables are most important?

3) What can be inferred about the prospect of cogeneration technology penetration in this utility market area from the results of this study?

If non-economic issues restrict penetration of cogeneration technology in the energy market of a utility service territory, it should be possible to find organizations which have facilities with
energy use characteristics conducive to cogeneration but policies which, to date, have restricted use of the technology.

1.3 RESEARCH DESIGN

The research design utilized a two-step procedure involving a mailed-out questionnaire and a follow-up telephone call or personal visit. The population of respondents is all commercial and industrial customer accounts with a monthly KW demand level of greater than 750 KW.

Each potential respondent organization received a telephone call to identify the correct individual's name and address. In approximately 3 cases in 10, M.I.T. Energy Laboratory staff were able to talk directly to the individual who would complete the questionnaire and encourage that person to cooperate. In this initial stage four potential respondents refused to participate.

The questionnaire was mailed April 1 and a follow-up card was mailed to all non-respondents on April 15. Selective telephone calls on incomplete responses were made up to May 30. To pursue other issues raised in conversations with respondents, a telephone interview or site visit took place with a selected group of respondents.
Since 1975, the Federal government, state governments, a number of electric utilities, and a few private organizations have studied cogeneration. The most important of these studies have been RPA (1976, 1980); Thermoelectron (1976); M.I.T. (1978, 1982); and Dow (1975). The strongest statement one can make about these studies is that they are diverse, and usually overstate the potential for cogeneration. Joskow (1981, p. 26) notes the "estimated economic potential for cogeneration varies quite widely among the studies. Estimated energy saving associated with cogeneration vary by an order of magnitude. Estimates of additional electricity production and equivalent base-load generating capacity vary by more than an order of magnitude."

The conclusions of these earlier studies were:

1) With the exception of Thermo Electro (1976), all studies either conclude or assume steam turbine cogeneration systems using coal are the most economical choice.

2) Diesel and gas turbine systems are not as economical as coal fired steam turbine systems.

3) Oil fired steam turbine systems are less economic than coal fired but more economic than diesel or gas turbines (at least in the Northeast). (Pickel, 1982)

2.1 NON-ECONOMIC ISSUES

Nearly all of the cogeneration studies raised questions about the effect of non-economic issues on the decision to invest in
cogeneration. The amalgam of non-economic issues from the literature fall into nine different classifications. A typology of these issues, and the reports from which the issues are derived, is listed in Figure 2.3.

The nine classifications were:

1) **Regulation - Utility**

Utility regulation is cited in at least a dozen studies as the prime disincentive for private organizations to cogenerate. The nature of electric utility regulation does, in fact, make any organization selling electricity subject to regulation in most states. In Massachusetts, for example, sale of any electricity outside of the organization makes the seller a utility under chapter 164 section 1, 2 and 3. (Massachusetts Statutes Annotated, 1978)

2) **Regulation - Environmental**

The same publications cite environmental control laws as a major detriment to cogeneration. The laws are voluminous and their application uncertain due to the imprecise nature of the regulations and due to their use on a site specific basis.

3) **Utility Attitude**

Sources of comments about utility attitude and cogeneration are found in eleven of the publications. Two of these appear frequently. First, utility advocacy is desired to enhance opportunities for cogeneration. Second, utility participation is preferred, particularly by small industries and, by implication, small commercial and institutional users to allow the small firms access to qualified operations personnel without the expense of maintaining them as full time employees.

4) **Line of Business**

A few publications point to one corporate strategic decision which is a prerequisite for consideration of cogeneration. A company must want to be self sufficient in energy. Otherwise, industry management is reluctant to become involved in what is considered a highly regulated and capital intensive activity, electric generation.
5) Uncertainty

A number of reports point to the lack of certainty about regulations, price of fuels in the future, and consistency of economic signals. In speaking directly to the price issue Joskow notes: "Future price uncertainty (of electricity) makes future profits random variables. The more firms are risk-averse, the more they will shy away from diesel and gas turbine cogeneration in favor of steam turbine cogeneration or no cogeneration at all." (Joskow, 1981, p. 59)

6) Financial limits

Ten of the publications point to one or more elements of financial constraints upon the use of cogeneration systems. Most of the citations argue that cogeneration is alien to the industries normal line of business and therefore industry adds a discount premium to the cost of capital to account for this added risk. Other reports focus on absolute limits to capital implicit in poor economic conditions. In either case, the implication of risk adjustment or capital limits is a higher cost to a firm wishing to cogenerate.

7) Market imperfections in pricing

Four publications specifically mention market imperfections in setting of electric utility rates as a major disincentive to cogeneration. Pickel points to "price disincentives" such as ratchet charges for KW demand used by a cogenerator as a prime problem. (Pickel, 1982, pp. II-49, II-50) Joskow and Jones (1981) argue that utility electric prices not equal to marginal cost cause equivalent problems.

8) Timing

Only two papers raised the important question of timing of cogeneration investment. In this case, the difference between the economic life of a cogeneration unit and the planning horizon of a company is listed as a significant problem preventing cogeneration. Beyond the issue of lead time mentioned by Brown, there is an issue I would call a planning window. For cogeneration to be selected at all, it must meet all investment criteria of the organization and do so at a time when the decision to engage in physical plant expansion or retrofit is being made. (Bulpitt, personal communication) This planning window occurs within a short period of time and under somewhat constrained conditions. Intuitively, these conditions include:

a) Impending retirement of existing physical plant at the same time expansion of capacity is to occur. Cogeneration may be sized to handle both retired boiler and expansion.

b) Expansion of capacity - Cogeneration typically is sized to handle expanded capacity.
9) **Power pool relations**

Only one study mentioned relations within an electric power pooling agreement as a possible problem for cogenerators. In this case, the report recommended the utility companies in a power pool allow a cogenerator to sell power to any other utility in the pool as a way of providing the cogenerator with maximum bargaining power.
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<tr>
<th>ISSUE</th>
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<td>Utility</td>
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<td>Dow (1975)</td>
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<td>RPA (1977)</td>
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<td>Belding (1982)</td>
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3.1 DEVELOPMENT

A mailed-out survey was used to build the core of the analytic data base. The questionnaire consisted of 3 segments: 1) Identification and screening information, 2) Policy questions to evaluate various elements of strategic, long-range, or operational planning, and 3) Physical plant characteristics and energy use for a specific facility.

3.2 COGENERATION DECISION VARIABLES

There are five key types of interrelated information needed to evaluate the effect of decision variables on adoption of cogeneration. Within these five areas, this study developed a set of variables which measure attitudinal responses from individuals who manage a facility, descriptive variables which measure behavior and physical conditions, and variables which measure potential choice. These five types of questions cover identification variables, strategic planning, long range planning and operational planning issues, and physical plant characteristics. Within the area of long range planning, the research explores two important subsets of information. First, the study determines the method of calculating
the worth of a cogeneration investment including the calculation methodologies and discount rates used. Second, it evaluates perceptions of factors which might increase risk to a firm and therefore increase cost. Within the areas of operation planning the study evaluates two important aspects of the problem. First, the method a company uses to engage in manager performance evaluation will heavily influence the managers planning of long term capital improvements. Second, the degree of efficiency in physical plant operation may heavily influence the decision to cogenerate. The five survey areas are summarized below. Distributions of responses to all attitudinal questions appear in chapter 4 of this report.

3.2.1 Identification

There are seven variables used to develop descriptive information on each respondent. This identification information is used to classify respondents and to identify differences in response between organizations.

Variables include:

- organization type
- SIC classification
- organization function
- facility use
- electricity account number area served
- square feet
- facility ownership, lease, or rental
3.2.2 Strategic Planning

This study differentiates strategic planning from long range planning on the basis that strategic planning provides a sense of direction about the company and policies for evaluation while long range planning sets out realistic capital budgets to achieve those policies.

There are a number of strategic issues related to energy use at a facility. These strategic issues for cogeneration include two dimensions of energy policy (energy conservation and fuel switching) and policy on joint ventures for energy projects.

Variables include:
- Energy independence
- Energy independence from utility
- Energy efficiency
- Reduce oil imports
- Joint funding energy projects
- Joint funding with utility
- Joint funding with utility impossible
- Energy conservation projects low priority
- Availability of financing prohibits cogeneration
- Economy limits cogeneration
- Regulation as utility
- Good utility relations limit cogeneration
- Cogeneration viable investment
- Scarce oil use vs. savings

3.2.3 Long Range Planning

Long range planning, management control and capital budgeting are different names for the second stage of an organization's planning process. Given the goals and policy laid out in the strategic planning process, how does management implement these goals.
components of capital budgeting analysis involve a forecast of the benefits and costs of a project, discounting the funds invested in a project at an appropriate rate, assessing the risk associated with the project, and follow up to determine if the project is performing as expected" (Clark, 1979, p. 4).

There are three groups of questions related to long range planning for cogeneration. These questions include financial issues, timing of investment, and uncertainty about regulation. In many cases these issues interrelate so that the effect of perceptions about one issue provides input into the solution of a second issue. For example, a firm may determine a project hurdle rate, a minimum rate of return which a project must exceed to be funded. The perception that delay due to the air quality regulation approval process increases risk may be (incorrectly) evaluated by adding an interest rate premium to the hurdle rate.

Similarly, the issue of timing may prove to be significant in conjunction with the discount rate. A short planning horizon is usually associated with a high discount rate and an emphasis on short term returns. Such an emphasis on the short term works to the detriment of capital improvements because investment characteristically reduces return on investment in the early years of a project.

Variables include:

**Finance issues**
- Financing prohibits cogeneration
- Primary calculation method
- Second calculation method
- Third calculation method
- Discount (interest) rate
- Interest rate premium
- Capital budget limits
Finance issues relating to cogeneration fall into two broad categories. First, does the plant manager or engineer perceive capital as a limited item. In budgetary systems, there are usually administratively imposed limits on capital budget items. The relative perception on the part of engineer or manager of capital budget limits may artificially restrict investment by ruling out in advance consideration of a capital intensive investment. The second issue of finance for cogeneration is whether the investment is "properly" valued. Two problems characteristically arise in evaluation of capital items.

1) Which calculation method is appropriate for evaluating the worth of a project

2) What rate of interest should be charged for use of funds

The calculation methods included in the study are listed in Figure 3.1 below and categorized by type.

Figure 3.1
CALCULATION METHODS

<table>
<thead>
<tr>
<th>Judgement</th>
<th>Accounting</th>
<th>Index</th>
<th>Cash Flow</th>
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<tbody>
<tr>
<td>Experience and Judgement of Managers</td>
<td>Accounting Rate of Return</td>
<td>Payback Profitability Index</td>
<td>Net Present Value</td>
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<td></td>
<td>Return on Investment</td>
<td>Index</td>
<td>Internal Rate of Return</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Annual Capital Charge</td>
</tr>
</tbody>
</table>
Timing issues are considered in one of three ways. First, the effect of general economic conditions on capital budget decisions is considered in variable 19. Second, the planning horizon commonly used for energy conservation capital improvements provides a fair indication of the willingness of an organization to plan long term investments. Third, the years to retirement of the main heating plant gives an indication of the planning window for selection of a cogeneration plant.

**Timing issues**
- Economy limits cogeneration
- Planning horizon
- Years to retirement

Uncertainty issues revolve around either the relationship between the organization which desires to cogenerate and the electric utility or between the potential cogenerator and government regulations. One added element of uncertainty in the price picture for cogeneration, and therefore for planning cogeneration systems, is the effect of the Public Utility Regulatory Policies Act (PURPA). This act is Title II of the National Energy Act of 1978 and contains two sections which directly affect the potential cost-effectiveness of cogeneration systems.

**Uncertainty issues**
- Changing air quality regulations
- Changes in air quality regulations will cause expense
- Electricity production for own use
- Electric sale price limits cogeneration
- Regulation as a utility
- Backup charges prevent cogeneration
- PURPA Awareness
- Cogeneration policy change due to PURPA
3.2.4 Operational Planning

Operational planning, operational control, tactical planning, and operating budget planning, are synonymous terms to define "the process of measuring that specific tasks are carried out efficiently and effectively" (Lorange, 1972, p. 4).

The operation planning elements of the survey look at two types of information. First, there are a number of questions which measure perceived limits of cogeneration systems or operating objectives. The second group of questions comprises the final one half of the survey. These questions evaluate physical characteristics of the facility and establish operational conditions.

Variables include:

Operational
- Personnel limits cogeneration
- Make up water supply limits cogeneration
- Electric production for our own use

Physical
- Load diversity for a 24 hour period in four hour blocks
- Present cogenerator
- Proportion KWH cogenerated
- Proportion KW cogenerated
- Heating plant type
- Heating fuel
- Previous heating fuel
- Cooling plant
- Percent high pressure steam
- Percent low pressure steam
- Percent hot water
- Energy conservation activities commonly available for commercial and industrial buildings
- Heating fuel reduction since 1972
- Electric energy reduction since 1972
Operational questions garner information about operating protocols or perceived limits to operations. Two policy questions look at production levels of electricity while two other questions focus on operating limitations of personnel or make up water.

The second group of variables may be broken into three subgroups. These are physical plant operating characteristics, physical plant description, and energy conservation activities. Physical plant operating characteristics include load diversity, steam load and hot water load. Physical plant description includes heating and cooling plant type and fuel switching in previous years. Finally, energy conservation includes the type of conservation activity accomplished and amount of energy saved since 1972.

3.2.5 Energy Use

The most important factor in consideration of traditional cogeneration systems is process energy use. However, significant evidence exists to argue that systems may now be designed to be electric load following. With PURPA regulations, the ability to sell excess power to the electric utility provides the opportunity to take advantage of electric load following cogeneration to use greater electricity production from any cogeneration capacity.

Energy use figures for each type of fuel consumed in the facility, including KW demand, and the proportion of energy used for process, is the final segment of the study. These responses are used to calculate an additional variable for million Btu of thermal energy.
4.1 DATA PREPARATION

Survey responses were received from organizations representing 170 electric accounts, 42.5 percent of the population. Of these responses, forty-one (41) were refusals to participate on the grounds that cogeneration was not applicable to the organization in question. Generally, this group of courteous, negative responses included multi-family residential units, traction power units for subways, and total electric buildings. Usable responses for 129 accounts, 32.25 percent of the population, were screened for multiple account numbers serving one physical location; 12 responses were combined as they represented the same physical location thus leaving a total of 117 responses for analysis.

There was a telephone follow up on significant omitted information within three weeks of response arrival. Significant information is limited to energy use, square feet, discount rates and planning horizon, fuel type, and heating plant type.

4.1.1 Tests for Reliability

Five of the variable pairs were designed to check internal reliability of responses. Results of these reliability tests are mixed. The first three pairs have both high gamma scores* and have
the expected sign. The fourth pair were expected to have a high degree of discordance, but, in fact, have a low degree of concordance. This means knowing that respondents favor energy independence from foreign sources will not help very much in predicting whether a respondent will seek to supply their own electrical needs. Similarly, we expected a negative relationship and high gamma score for the last variable pair. In this case, knowing a company would consider a jointly funded project only with the electric utility was expected to be diametrically opposed to an answer that under no circumstances would an organization engage in a jointly funded project with a utility. While the direction is correct, the gamma score is lower than expected.

4.1.2 Tests for Bias in Response

The key question in testing for consistency in distribution of responses between respondents and total population is whether the respondents are proportionally representative of the total population. In this case, there are no statistically significant differences in response proportions by ownership, organization function, title of individual contacted, or KW demand.

* Gamma is the number of concordant pairs minus the number of discordant pairs divided by the total number of pairs. The value of gamma can be taken as the probability of correctly guessing the order of a pair of cases on one variable once the ordering on the other variable is known (Nie, et. al., 1975).

\[
\text{GAMMA} = \frac{P - Q}{P + Q}
\]
Table 4.1

KW DEMAND COMPARISON

<table>
<thead>
<tr>
<th>POPULATION</th>
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<tr>
<td>RELATIVE FREQ.</td>
<td>RELATIVE FREQ.</td>
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<tr>
<td>Percent</td>
<td>Percent</td>
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<td>750-949 KW</td>
<td>142 35.6</td>
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<td>2150-2349 KW</td>
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</tr>
<tr>
<td>3150-3349 KW</td>
<td>4  1.0</td>
</tr>
<tr>
<td>3350-3549 KW</td>
<td>3  0.8</td>
</tr>
<tr>
<td>3550-3749 KW</td>
<td>4  1.0</td>
</tr>
<tr>
<td>3750-3949 KW</td>
<td>1  0.3</td>
</tr>
<tr>
<td>3950-4149 KW</td>
<td>2  0.5</td>
</tr>
<tr>
<td>4150-HIGHEST KW</td>
<td>35 8.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>399 100.0</td>
</tr>
</tbody>
</table>

4.2 DESCRIPTION OF RESPONDENTS

4.2.1 Strategic Questions

Table 4.2 contains a tabulation of survey results for strategic questions. Twenty nine respondents (22 percent) indicate cogeneration is a viable technology for their facility. When asked if cogeneration would be ignored, even though cost effective, to avoid increased use of imported oil, 42 percent of respondents disagreed. Neither the
possibility of an organization being regulated as a utility (25 percent disagree) nor the risk of poor relations with a utility (40 percent disagree) would strongly affect the decision to use cogeneration, assuming it was cost effective at a facility.

4.2.2 Long Range Planning Questions

Financing questions discuss the planning horizon for capital budgeting items, the calculation method used for evaluating a potential cogeneration system, discount rates and discount rate premiums used. The planning horizon provided by most respondents (47 percent) was five years. Only four respondents indicated a planning horizon longer than five years where one indicated eight years and three respondents would use ten years. Respondents indicated they would use payback and ROI (Return on Investment) by a wide margin as both the primary method (67.1 percent) and secondary method (61.1 percent) of calculation. Only in the third method used would managers rely upon judgement (24 percent) or use an annual capital charge method (17 percent) more often than payback or ROI (each 13.7 percent). These results are at odds with financial theorists who would argue in favor of discounted cash flow methods.

The discount rate which would be used in calculations of discounted cash flows is an indicator of the perceived cost of capital for a firm. We used the Capital Asset Pricing Model to develop a rough estimate of the cost of capital for an electric generation investment. The calculated estimate of the discount rate is roughly
<table>
<thead>
<tr>
<th>Variable number and name</th>
<th>STRONGLY AGREE</th>
<th>MODERATELY AGREE</th>
<th>NEUTRAL</th>
<th>MODERATELY DISAGREE</th>
<th>STRONGLY DISAGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAR010 - Our organization policy supports federal government policy favoring energy independence from foreign energy sources.</td>
<td>63(56.8)</td>
<td>23(20.7)</td>
<td>25(22.5)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>VAR011 - Organization policy strongly favors energy independence from our utility - our organization will actively seek to supply our own electrical energy needs.</td>
<td>3(2.7)</td>
<td>14(12.0)</td>
<td>43(36.8)</td>
<td>17(14.5)</td>
<td>34(29.1)</td>
</tr>
<tr>
<td>VAR012 - Our organization actively engages in energy conservation work at this facility, seeking to achieve the most efficient use of energy resources.</td>
<td>86(76.1)</td>
<td>24(21.2)</td>
<td>2(1.8)</td>
<td>1(0.9)</td>
<td>--</td>
</tr>
<tr>
<td>VAR013 - Our organization actively engages in energy conservation work at this facility to reduce oil and natural gas consumption and therefore US oil imports.</td>
<td>74(65.7)</td>
<td>24(22.2)</td>
<td>12(11.1)</td>
<td>1(0.9)</td>
<td>--</td>
</tr>
<tr>
<td>VAR014 - Official policy favors having this organization enter into jointly funded energy projects.</td>
<td>16(14.4)</td>
<td>10(9.0)</td>
<td>62(55.9)</td>
<td>11(9.9)</td>
<td>12(10.8)</td>
</tr>
<tr>
<td>VAR015 - Assuming we were to cogenerate, we would consider a jointly funded project at this facility ONLY if our electric utility is willing to be the joint partner.</td>
<td>9(8.2)</td>
<td>23(20.9)</td>
<td>46(41.8)</td>
<td>19(17.3)</td>
<td>13(11.8)</td>
</tr>
<tr>
<td>VAR016 - Under NO circumstances would this organization engage in a jointly funded project with an electric utility.</td>
<td>6(5.5)</td>
<td>8(7.3)</td>
<td>49(45.0)</td>
<td>27(24.8)</td>
<td>19(17.4)</td>
</tr>
<tr>
<td>VAR017 - An official policy of energy conservation would make no sense at this facility because we have many more important uses for our money.</td>
<td>1(0.9)</td>
<td>4(3.9)</td>
<td>9(8.3)</td>
<td>24(22.0)</td>
<td>71(65.1)</td>
</tr>
<tr>
<td>VAR018 - Availability of financing effectively prohibits cogeneration for us.</td>
<td>8(7.4)</td>
<td>30(27.8)</td>
<td>38(35.2)</td>
<td>17(15.7)</td>
<td>15(13.9)</td>
</tr>
<tr>
<td>VAR019 - Assuming we wanted to invest in cogeneration We wouldn't do it until the economy improves.</td>
<td>6(5.6)</td>
<td>31(28.7)</td>
<td>42(38.9)</td>
<td>18(16.7)</td>
<td>11(10.2)</td>
</tr>
<tr>
<td>VAR036 - We are generally happy with the service our electric utility provides us and would not be inclined to risk our good relations by generating electricity on our own.</td>
<td>12(10.9)</td>
<td>15(13.6)</td>
<td>39(35.5)</td>
<td>27(24.5)</td>
<td>17(15.5)</td>
</tr>
<tr>
<td>VAR037 - We believe cogeneration is a viable cost saving investment for us at this facility.</td>
<td>8(7.3)</td>
<td>21(19.1)</td>
<td>50(45.5)</td>
<td>22(20.0)</td>
<td>9(8.2)</td>
</tr>
<tr>
<td>VAR038 - Even if oil fired cogeneration were cost effective here, we would still not invest since it would mean we would consume more scarce oil.</td>
<td>4(3.7)</td>
<td>14(12.8)</td>
<td>42(38.5)</td>
<td>35(29.9)</td>
<td>14(12.0)</td>
</tr>
</tbody>
</table>
17.5 percent. The majority of discount rates cited by respondents were at or below that estimate (69.5 percent). The lowest estimates come from local and state government and private non profit organizations while consistently higher estimates come from private organizations. Adding interest premium estimates to the discount rates still yields 60 percent of respondents at or below the CAPM estimated discount rate.

Finally, long range planning contains uncertainty due to regulation, environmental or utility, pricing of potential electricity output, and upcoming changes in Federal regulations due to PURPA. All of these questions use five point agree - disagree scale answers. Variable 41 uses different terminology to describe the scale response, ranging from definitely will make a difference in company policy toward cogeneration to definitely would not make a difference.

PURPA, designed as legislation to give organizations bargaining power if they choose to cogenerate, is an unknown factor at the present. Forty-nine percent of respondents were not familiar with PURPA and an additional 31 percent were only somewhat familiar with PURPA.

4.2.3 Operational Planning

Two aspects of operational planning are included in this study. First, a small number of questions look at operating policy constraints. Second, a much larger group of questions looks at a rough cut indication of present operating conditions.
<table>
<thead>
<tr>
<th>Variable number and name</th>
<th>STRONGLY AGREE FREQ. (%)</th>
<th>MODERATELY AGREE FREQ. (%)</th>
<th>NEUTRAL FREQ. (%)</th>
<th>MODERATELY DISAGREE FREQ. (%)</th>
<th>STRONGLY DISAGREE FREQ. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAR030 - Air quality regulations create severe planning problems for us because we feel they change too much over time.</td>
<td>7(6.4)</td>
<td>20(17.1)</td>
<td>50(42.7)</td>
<td>25(21.4)</td>
<td>8(6.8)</td>
</tr>
<tr>
<td>VAR032 - Changes in air quality regulation will cause heavy and unexpected expenses if we cogenerate.</td>
<td>9(8.2)</td>
<td>24(21.8)</td>
<td>50(45.5)</td>
<td>23(20.9)</td>
<td>4(3.6)</td>
</tr>
<tr>
<td>VAR033 - If we do decide to produce electricity, it will be for our own use with none left over to sell to the electric utility.</td>
<td>10(9.2)</td>
<td>24(22.0)</td>
<td>48(44.0)</td>
<td>21(19.3)</td>
<td>6(5.5)</td>
</tr>
<tr>
<td>VAR034 - We won't cogenerate because we can't get a fair price for our electricity sold to the utility.</td>
<td>1(0.9)</td>
<td>6(5.5)</td>
<td>63(57.8)</td>
<td>24(22.0)</td>
<td>15(12.8)</td>
</tr>
<tr>
<td>VAR035 - Our organization is concerned about regulation. If we sell any electricity outside the organization it may make us a regulated utility.</td>
<td>5(4.5)</td>
<td>18(16.4)</td>
<td>59(53.6)</td>
<td>22(20.0)</td>
<td>6(5.5)</td>
</tr>
<tr>
<td>VAR039 - Backup charges for electric energy purchased from the utility prevents cogeneration.</td>
<td>5(4.6)</td>
<td>8(7.4)</td>
<td>66(61.1)</td>
<td>19(17.6)</td>
<td>10(9.3)</td>
</tr>
<tr>
<td>VAR041 - PURPA provides that each State Public Utility Commission set rates for electric utilities purchase of electricity from cogeneration or small power producers. The law also states that qualifying cogenerators and small power producers will not be regulated. In your opinion, will knowledge about PURPA change your organization's policy towards cogeneration.</td>
<td>--</td>
<td>11(10.3)</td>
<td>42(39.3)</td>
<td>43(40.2)</td>
<td>11(10.3)</td>
</tr>
</tbody>
</table>
The five point scale questions indicate most organizations presently don't have personnel who are able to operate a cogeneration plant (54.9 percent). Conversely, make up water supply (21 percent agree it limits technology) and electricity sale price (6 percent agree it limits technology) do not appear to be a major limitation.

The questions on operating characteristics of the respondents are divided into three types. The first type defines the plant, the second type defines how the plant is used and the third type defines energy conservation activities accomplished. Among the last type of question, installation of a sophisticated electric load management system is an important indication that cogeneration will not be inaccurately valued for electric peak shaving (reduction of KW demand charges). Similarly, the most likely set of physical plant conditions which favor cogeneration is a steam system having condensate return and with air conditioning provided in part by an existing absorption chiller. Use of the physical plant should show very stable thermal energy use over the course of a work week, preferably with a three shift, seven day a week schedule uniform need for thermal and electric energy. The physical plant used by many respondents may be conducive to the addition of cogeneration technology. Forty five percent (45 percent) of respondents (53) have steam systems while an additional 19 percent (22) purchase steam from a commercial vendor. Of the 29 respondents who agreed to some extent that cogeneration was viable at their facility, twenty four (24) have steam systems at the facility or purchase steam.
Operational characteristics included present levels of cogeneration, (if any), hours of operation, and amount of steam and hot water use. Only 16 respondents used steam above 150 psig and the level of use ranged from 2 percent to 97 percent of heating energy requirements. Low pressure steam use (15-150 psig) occurred in 36 percent of the cases. Twenty-five percent of respondents used pressurized hot water to some degree ranging from 5 to 90 percent of heating energy.

Energy conservation activities of primary interest were load control devices installed to control peak demand. Only 27 percent of respondents installed load shedding while 56 percent had installed nighttime setback procedures. Thirty-six respondents (31 percent) have a load management system installed.

Load shedding or load management was reported by respondents as installed in only 9 of a potential 29 organizations where cogeneration is considered viable. While very preliminary, this does indicate that the assessment of cogeneration's viability may be based on an intuitive assumption of reduction in (KW) demand which could be unnecessarily large.

Finally, evidence exists that coal conversion will enhance the cost effectiveness of cogeneration of steam and electricity far more than any other single factor in the New England states. Yet, 96 of 117 organizations said consideration of use of coal is not likely, 2 considered and rejected coal use and only 5 indicated it would be considered or would be used. Consideration of coal derived fuel is
only slightly more likely. Nineteen respondents indicated they would consider coal derived fuels but 60 (56.6 percent) had not and were not likely to consider such fuels.

4.3 Underlying relations in the responses

The method chosen to define these underlying relationships is factor analysis (See Appendix B for a short description of Factor Analysis). Alpha factoring assumes the variables are part of a larger but unknown universe of all variables which could explain the phenomenon of cogeneration. Alpha factor analysis was used to identify the maximum generalizability of variables.

The "importance" of the factors is, in a very special and limited sense, that they successively explain smaller and smaller amounts of total variance common or shared by all variables in the data set. Consequently, the first factor derived may be considered the most important in explaining variation and therefore one can infer it is the most important of the factors.

Each of the derived factors is discussed below:

Factor 1 - COST UNCERTAINTY DUE TO REGULATION

With the exception of variable 17 (more important uses for money than energy conservation) the remaining variables describe the volatility and expense of regulation.
Factor 2 - SELF SUFFICIENCY
These variables pertain to the degree of energy self sufficiency a utility customer seeks. Cogeneration requires a high degree of energy self sufficiency. These variables indicate the stronger the agreement with independence from the utility the more viable cogeneration appears to the respondents and the more likely it is respondents will not change their attitude due to PURPA.

Factor 3 - PRESENT COGENERATOR
Two variables isolate the level of present cogeneration from the remaining factors. The strength of the factor loadings for these two variables indicates that they are not at all correlated with the other factors.

Factor 4 - CONSERVATION OBJECTIVES
Corporate policy and its relation to cogeneration is factor 4. Respondents express a strong support for energy efficiency. While the coefficient for variable 13 is negative, the interpretation of this coefficient supports strong energy conservation objectives as a factor in the decision to adopt cogeneration technology. The question is worded to determine if respondents would not adopt oil fired cogeneration, even if it were cost effective, since adopting cogeneration under these circumstances would increase use of imported oil.
Factor 5 - FINANCIAL FLEXIBILITY
All three variables loading on this factor refer to some limitation upon available finances, either imposed by the financial markets or by company policy.

Factor 6 - JOINT VENTURES POLICY
Respondents are not generally open to jointly funded projects but are open to having the utility involved as a joint partner if they were to cogenerate.

Factor 7 - UTILITY PRICE CONSTRAINTS
Both make-up water supplies and electricity pricing for purchase of electricity from an organization by a utility do not have a part in determining a decision to cogenerate. These questions were both negatively worded in the survey and, consequently, have positive factor loadings.

Factor 8 - HUMAN RELATIONS
Both variables load highly and positively on the factor, indicating neither personnel limits nor good utility relations are going to limit adoption of cogeneration technology if the technology is cost effective.
Factor 9 - COST OF CAPITAL
The discount rate loads highly and negatively on factor 9. This loading pattern indicates that as discount rates get higher the relationship with cogeneration is higher. This anomaly comes from responses by private sector firms which both use discounted cash flow methods and higher discount rates compared to public sector respondents.

Factor 10 - TIMING
The economic cycle does have an effect on the decision to choose cogeneration.

Factor 11 - INVESTMENTS POLICY
Cogeneration, a cost saving investment, requires that an organization has a policy which allows cost saving investment as well as revenue production. Positive loading on variable 31 indicates that investment policy may be a factor in use of cogeneration.

Factor 12 - PLANNING FACTORS
The final factor consists of the primary method respondents used for evaluating the cost effectiveness of adopting cogeneration.

In sum, the factor analysis confirms what we already saw in anecdotal references in the literature. There are a number of factors, other than strictly economic evaluations, which may affect
the decision to adopt cogeneration. Strongest among these factors are:

- Uncertainty caused by regulatory action;
- Desire for energy self sufficiency by the organization;
- Financial flexibility;
- Experience with electricity cogeneration or self generation; and
- Capital budget planning methods.

4.4 Results of Discriminant analysis

4.4.1 Selection of Variables for Analysis

From the 92 possible variables in the survey we selected a subset of 42 variables for discriminant analysis. These variables included square feet of floor space, all questions related to organization policy, hours of operation for the facility, and energy use.

Eleven variables entered the stepwise discriminant analysis solution and remained after testing for significance. Table 4.4 lists the discriminating variables and their short labels. The order in which variables enter the discriminant function is not an indication of the importance of the variable. The importance of a variable in explaining a discriminant function is determined by the canonical discriminant function coefficients. Table 4.5 contains these coefficients.

The size and direction of the coefficient is a significant indicator of the importance of each of these variables in the decision
to use cogeneration. We divide the variables into two groups: policy and physical variables.

Table 4.4
VARIABLES ENTERING DISCRIMINANT FUNCTION

<table>
<thead>
<tr>
<th>STEP</th>
<th>LABEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hours of operation per year</td>
</tr>
<tr>
<td>2</td>
<td>Viable investment this facility</td>
</tr>
<tr>
<td>3</td>
<td>Reduce oil imports</td>
</tr>
<tr>
<td>4</td>
<td>Scarce oil versus energy savings</td>
</tr>
<tr>
<td>5</td>
<td>Electric sale price limits cogeneration</td>
</tr>
<tr>
<td>6</td>
<td>Personnel limits</td>
</tr>
<tr>
<td>7</td>
<td>Electric demand peak month KW</td>
</tr>
<tr>
<td>8</td>
<td>Good utility relations limit</td>
</tr>
<tr>
<td>9</td>
<td>Joint funding - utility</td>
</tr>
<tr>
<td>10</td>
<td>Million BTU per square foot</td>
</tr>
<tr>
<td>11</td>
<td>Air quality regulations : expense</td>
</tr>
</tbody>
</table>

Policy variables fall into one of two types, strategic or operational. Strategic questions include variables 13, 15, 36, 37, and 38. Variable 13 argues that even if cogeneration were cost effective, the organization would not invest because it would require increased consumption of scarce oil. The relatively low and negative coefficient indicates the differences were not great, but cogenerators would tend to disagree with the argument of the question. Variable 15 argues the organization, if it were to cogenerate, would do so only if the utility were a joint partner. Again, existing cogenerators differed from non cogenerators in being much less interested in joint cogeneration projects. Variable 36 argues the organization would not
Table 4.5
CANONICAL DISCRIMINANT
FUNCTION COEFFICIENTS

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>NAME</th>
<th>COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAR013</td>
<td>Reduce oil imports</td>
<td>-0.23687</td>
</tr>
<tr>
<td>VAR015</td>
<td>Joint funding - utility</td>
<td>-0.42626</td>
</tr>
<tr>
<td>VAR027</td>
<td>Personnel limits</td>
<td>-0.47901</td>
</tr>
<tr>
<td>VAR032</td>
<td>Air quality regulations : expense</td>
<td>0.32050</td>
</tr>
<tr>
<td>VAR034</td>
<td>Economy limits cogeneration</td>
<td>0.48813</td>
</tr>
<tr>
<td>VAR036</td>
<td>Good utility relations limit</td>
<td>0.34002</td>
</tr>
<tr>
<td>VAR037</td>
<td>Viable investment this facility</td>
<td>0.48272</td>
</tr>
<tr>
<td>VAR038</td>
<td>Scarce oil versus savings</td>
<td>-0.50754</td>
</tr>
<tr>
<td>HOURS</td>
<td>Hours of operation per year</td>
<td>-0.67483</td>
</tr>
<tr>
<td>VAR080</td>
<td>Electric demand peak month KW</td>
<td>0.46693</td>
</tr>
<tr>
<td>MBSQ</td>
<td>Million BTU per square foot</td>
<td>0.35741</td>
</tr>
</tbody>
</table>

cogenerate because it might risk good relations with the electric utility. The positive coefficient of 0.34 indicates some positive but not very strong differences from non-cogenerators. Variable 37 asks if the respondent believes cogeneration to be viable at the facility in question. A positive coefficient of 0.48 indicates differences in the right direction and of substantial size between the two groups. Variable 38 argues oil fired cogeneration would not be used even if cost effective because it would increase use of imported oil. The
strong negative response indicates cogenerators would not follow that line of reasoning.

Three variables consider operational issues of a cogeneration system. As is to be expected, cogenerators did not consider personnel to limit their ability to cogenerate (VAR027) and the strong negative coefficient bears this out. However, variable 34 has a strong positive difference (coefficient of 0.48) between the two groups. Similarly, there is a small positive difference between the two groups over the issue of air quality regulations causing unexpected expense.

Finally, three physical variables are used in the analysis. KW demand is measured directly from responses to question 52. However, two other variables have been calculated. Hours is an estimate of the number of hours per year a facility will operate. It is based on question number 38 of the survey. Hours is calculated by estimating a percentage use figure for each four hour period of a typical work week and multiplying by 52 weeks per year. MBSQ is calculated by converting all energy use in a facility to millions of British Thermal Units and dividing by the number of square feet in the facility. Both variable 80 and MBSQ have a positive relationship while the strongest discriminating variable HOURS has a negative relationship between groups.

To check on the quality of the discriminant function developed in the analysis section, each case was classified according to their variables as members of either group 1 (cogenerators) or group 2 (non-cogenerators). Table 4.6 indicates the results of the
classification.

Table 4.6
PREDICTED GROUP MEMBERSHIP

<table>
<thead>
<tr>
<th>ACTUAL</th>
<th>NO. OF CASES</th>
<th>PREDICTED GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (cogenerator)</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>2 (non-cogenerator)</td>
<td>112</td>
<td>8</td>
</tr>
</tbody>
</table>

Percent of "grouped" cases correctly classified: 93.10

In sum, discriminant analysis appears to be a good technique for determining those facilities which have characteristics which could make them good prospects for adoption of cogeneration technology. This technique of stepwise discriminant analysis identifies those organizations which do not cogenerate and determines if they should be "grouped" with those organizations which do cogenerate.

For the electric utility territory in question, we found very few facilities which do have characteristics conducive to adoption of steam turbine cogeneration technology. Of the 112 non cogenerators who participated in this study, only five had characteristics conducive to adoption of cogeneration. Three facilities are manufacturing plants with double or triple shift operations, one is a complex of office buildings and hotel/convention space, and one is a hospital.
BIBLIOGRAPHY


APPENDIX B

ANALYSIS METHODS

FACTOR ANALYSIS

DISCRIMINANT ANALYSIS
Factor Analysis

To find a means of generalizing a set of common factors existing in a universe of variables given a sample of variables, we use alpha factor analysis. Alpha factor analysis as developed by Kaiser and Caffrey requires "that the common factors of the sample of variables be determined so that they have maximum correlation with those in the corresponding universe of variables. The square of these correlations is \( \alpha^g \), a coefficient of generalizability. The generalizability factor is a linear function of the corresponding eigenvalue. For any factor \( F_e \),

\[
\alpha^g_e = \left( \frac{M}{M-1} \right) \left( \frac{\lambda_i - 1}{\lambda_i} \right)
\]

Where:
- \( \alpha^g_e \) = coefficient of generalizability
- \( m \) = variables
- \( \lambda_i \) = associated eigenvalue

Alpha factors with eigenvalues greater than one enable common factors existing in the universe of content to be retained in the alpha factor solution.

Factor loadings are rotated to reduce the complexity of the factor description of the variables. Rotation techniques used in this study
are both orthogonal, e.g. I do not assume any correlation between factors. The two rotation techniques used are quartimax and varimax. Quartimax minimizes the sum of the products of all possible pairs of factor loads for a variable. Varimax maximizes the variance of the squared factor loadings in each column.

**Discriminant Analysis method**

Discriminant analysis begins with a desire to distinguish statistically between two or more groups of cases. "The mathematical objective of discriminant analysis is to weight and linearly combine the discriminating variables in some fashion so that the groups are forced to be as statistically distinct as possible." These "discriminant functions" are of the form

\[ D_i = d_{i1}Z_1 + d_{i2}Z_2 + \ldots + d_{ip}Z_p \]

Where:

- \( D_i \) = Score on discriminant function \( i \)
- \( d_{ij} \) = Weighting coefficient
- \( Z \) = Standard values of the \( p \) discriminating variables

----

* This material is adapted from Nie et al. (1975).
The discriminant function is useful in two ways. These two uses are analysis and classification of cases. "The analysis aspects of this technique provide several tools for the interpretation of data. Since the discriminant functions can be thought of as the axes of a geometric space, they can be used to study the spatial relationships among the groups. More importantly, the weighting coefficients can be interpreted much as in multiple regression or factor analysis. In this respect, they serve to identify the variables which contribute most to differentiation along the respective dimension (function)." (Nie et al. 1975 pp.435)

The use of discriminant analysis as a classification technique comes after the initial computation. Once a set of variables is found which provides satisfactory discrimination for cases with known group memberships, a set of classification functions can be derived which will permit the classification of new cases with unknown memberships. To check on the adequacy of the original discriminant functions, we classify the original set of cases to see how many are correctly classified by the variables being used. The procedure for classification involves the production of a probability of membership in the respective group, and each case is assigned to the group with the highest probability. "The traditional classification equations are derived from the pooled within-groups covariance matrix and the centroids of the discriminating variables. The resulting classification coefficients are to be multiplied by the raw variable
values, summed together and added onto a constant" (Nie et al. 1975 p.436). The equation for one group would appear as

\[ C_i = c_{i1}V_1 + c_{i2}V_2 + \ldots + c_{ip}V_p + c_{i0} \]

Where:

- \( C_i \) = Classification score for group \( i \)
- \( c_{ij} \) = Classification coefficients
- \( c_{i0} \) = Constant
- \( V \) = Raw score on the discriminating variable

The rule of assigning a case to the group with the highest score is then equivalent to assigning the case to the group for which it has the greatest probability of membership.

This study uses a stepwise procedure to develop the discriminant function. The stepwise procedure begins by selecting the single best discriminating variable according to the overall multivariate F ratio for the test of differences between group centroids. A second discriminating variable is selected as the variable best able to improve the value of the discrimination criterion in combination with the first variable. At each step, variables already selected may be removed if they are found to reduce discrimination when combined with more recently selected variables. The use of a stepwise procedure results in an optimal set of variables being selected. The canonical correlation tells how closely the function and the group variable are
related, which is just another measure of the function's ability to discriminate among groups. The canonical correlation squared is the proportion of variance in the discriminant function explained by the groups.

A second criterion for eliminating discriminant functions is to test for the statistical significance of discriminating information not already accounted for by the earlier functions. As each function is derived, starting with no (zero) functions, Wilk's lambda is computed. Lambda is an inverse measure of the discriminating power in the original variables which has not yet been removed by the discriminant functions - the larger lambda is, the less information remaining. The variable which maximizes the F ratio also minimizes Wilk's Lambda, a measure of group discrimination. This test takes into consideration the differences between all the centroids and the cohesion or homogeneity within groups.

The standardized discriminant function coefficients are of great analytic importance and correspond to the $d_{ij}$'s given in the formula above. Any single score represents the number of standard deviations that case is away from the mean for all cases on the given discriminant function. By averaging the scores for the cases within a particular group we arrive at the group mean of the respective function. For a single group, the means on all the functions are referred to as the group centroid, which is the most typical location of a case from that group. A comparison of the group means on each function tells us how far apart the groups are on that dimension. When
the sign is ignored each coefficient represents the relative contribution of its associated variable to that function. The sign denotes whether the variable makes a positive or negative contribution.