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MASTER

MARKETING OF COAL MINING EQUIPMENT --
EVALUATION OF PRESENT TECHNIQUES --
SUGGESTIONS TO AID COMMERCIALIZATION

FINAL REPORT

Prepared for
U.S. Department of Energy
Office of Coal Production Technology
12th and Pennsylvania Avenue, N.W.
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METRIC CONVERSION FACTORS

Approximate Conversions from Metric Measures

When You Know Multiply by To Find Symbol

LENGTH			
mm	millimeters	0.04	inches
cm	centimeters	0.4	inches
m	meters	3.3	feet
km	kilometers	1.1	yards
		0.6	miles

AREA			
mm ²	square millimeters	0.16	square inches
cm ²	square centimeters	1.2	square inches
m ²	square meters	0.4	square yards
km ²	square kilometers	2.5	square miles
ha	hectares (10,000 m ²)	2.5	acres

MASS (weight)			
g	grams	0.035	ounces
kg	kilograms	2.2	pounds
t	tonnes (1000 kg)	1.1	short tons

VOLUME			
ml	milliliters	0.03	fluid ounces
l	liters	2.1	pints
ml	liters	1.06	quarts
l	liters	0.20	gallons
ml	cubic meters	35	cubic feet
m ³	cubic meters	1.3	cubic yards

TEMPERATURE (exact)			
°C	Celsius	9/5 (then add 32)	Fahrenheit
°F	Fahrenheit	5/9 (after subtracting 32)	Celsius

Approximate Conversions to Metric Measures

When You Know Multiply by To Find Symbol

LENGTH			
in	inches	2.5	centimeters
ft	feet	30	centimeters
yd	yards	0.9	meters
mi	miles	1.6	kilometers

AREA			
in ²	square inches	6.5	square centimeters
ft ²	square feet	0.09	square meters
yd ²	square yards	0.8	square meters
mi ²	square miles	2.6	square kilometers
	acres	0.4	hectares

MASS (weight)			
oz	ounces	28	grams
lb	pounds	0.45	kilograms
	short tons (2000 lb)	0.9	tonnes

VOLUME			
teaspoons	5	milliliters	ml
tablespoons	15	milliliters	ml
fluid ounces	30	milliliters	ml
cups	0.24	liters	l
pints	0.47	liters	l
quarts	0.95	liters	l
gallons	3.8	liters	l
cubic feet	0.03	cubic meters	m ³
cubic yards	0.76	cubic meters	m ³

TEMPERATURE (exact)			
°F	Fahrenheit	5/9 (after subtracting 32)	Celsius
°C	Celsius	9/5 (after subtracting 32)	Fahrenheit

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EXECUTIVE SUMMARY

This report is an examination of the equipment preferences and decision-making methodology of the coal industry. The prime purpose is to indicate directions in which equipment research might proceed and also to indicate methods by which investment in new, more productive mining equipment could be encouraged. In addition to this, an investigation of the research and development decisions of major mining equipment manufacturers was conducted. The findings can best be condensed into three categories: needs for equipment in underground mining, needs for equipment in surface mining, and the purchase decision by coal mine operators.

Needs for Equipment in Underground Mining

1) There are no present economic or regulatory forces causing a return to conventional mining. Conventional mining is used only as a result of: lack of capital to purchase continuous miners, need to retain larger average particle size for antiquated processing plants, or need to mine coal containing much physical spoil. Other than for these three reasons, none of the interviewed companies used conventional mining.

Other aspects of conventional mining that tend to discourage its use are the skill levels and job descriptions of the tasks associated with it. It is often difficult for the respondents to locate and hire workers with the skills necessary for conventional mining. The bidding system and worker preferences have meant that experienced workers have bid out of work on conventionally mined faces. It has thus become difficult both to find skilled workers and to keep them in a conventionally mined section.

Health, safety, and ventilation rules also work against the retention of conventional mining. It is difficult to maintain the various phases of conventional mining and yet ensure ventilation standards and keep workers away from forward positions.

2) For the interviewed operators and manufacturers, specialized heads on continuous miners to increase particle size and decrease dust generation are not seen as beneficial efforts. Ventilation standards have obviated the need to control dust generation at the source. There is therefore no need to have low dust generation when ventilation costs cannot be commensurately decreased. None of the respondents had major problems dealing with the particle size produced by continuous miners, with the exception of those operators having processing plants unable to operate with coal produced totally by continuous mining.

3) In general, the type of equipment desired would have few mechanical or hydraulic linkages. Instead, an electric motor would be placed at every point where torque is needed.

4) Productive time of the continuous miner (actual extraction time at the face) is estimated by the respondents to be between 25-30% of total operating time. Whether this discontinuity of operation is due to shuttle car capacity or to the need for pullbacks for bolting appears to be a function of seam height -- the lower the seams, the more concern about shuttle car capacity. However, the consensus among the operators and manufacturers is that fully automated bolting is a sophistication whose benefits will not be realized until some form of continuous face haulage is also in place. While the fully automated bolter will certainly speed production, its

benefits will not be considerably larger than those of a less automated miner-bolter, due to the constraints of face haulage. There is a definite feeling that a miner-bolter must be developed, but also that it is not beneficial for one aspect of the extraction process to far exceed the capacity of another.

4) The need for extremely low-seam (20-25") continuous mining equipment is not being adequately met. Several of the respondents felt that, far from becoming an unimportant source of coal in the future, the low-seam coal will be heavily exploited.

5) Belts for face haulage are the obvious solution to the discontinuities of continuous mining. One operator had used belts in a room-and-pillar operation and thus had direct experience. His reactions to the types of belts he used were generally reflective of opinion by other operators who had not had direct experience. He reported it was difficult to get workers to bid for the job of belt movers. While he had experienced no safety problems, there were labor problems associated with belts.. All operators would like to see belts of some sort in place and can anticipate ways to accommodate them in their operation under present safety regulations. The manufacturers contacted felt that drive and support mechanisms were presently adequate, but that the belt itself will be the major problem. At present, there is no belt that can negotiate tight corners, retain its shape, hold the coal load, and resist rapid wear.

6) All operators felt that primary haulage would never be a constraint on their operations. Presently available belts and drives are totally adequate.

7) Roof control techniques other than bolting are not considered necessary. The bolting process itself, with its attendant costs and delays, is a problem. The delays will

have to be dealt with by a miner-bolter, but the cost is a factor becoming increasingly burdensome. Present standards mandate the standard placement of bolts, so lessening costs cannot come through using fewer, stronger bolts. Materials costs and weight could possibly be reduced to result in a cheaper bolt. Ease of placement and tensioning are two other areas open to improvement, in the opinion of the mine operators. Presently, these tasks are time-consuming and appear to be open to much improvement. The feeling among all the respondents is that several, low-cost solutions, such as using the bolt to actually do the drilling, could be examined, but, so far, have not been.

8) The concern with possible increasing production from low seams has made the development of an efficient low-seam bolter necessary.

9) The problem of maintaining air flows at the face was cited as the major area where new health and safety regulations have had the most severe impact on equipment purchases. The number and size of fans and baffles have been much greater than originally anticipated. It is here that the increased costs of operations from new regulations have been keenly felt. New methods of ensuring air flow would be welcome.

10) Proposed new noise regulations are not being considered in purchase and design of new equipment. Both manufacturers and operators expect major modifications.

Needs for Equipment in Surface Mining

1) In general, surface operators are well satisfied with the equipment they use.

2) The major problem that has arisen recently is that of topsoil segregation. The inclusion of scrapers in the

equipment fleet has meant an enormous increase in tire costs. Solutions to the problems of removal and replacement of topsoil have led to some inquiries on small, more maneuverable draglines.

3) Up-time is the sole criterion used to measure productivity in surface equipment. Only in recent evaluations have concepts like cycle time for buckets and draglines come to have a direct impact on decision-making.

4) Bucket-wheel excavators are not anticipated to be used in bituminous coal mining. Many of the problems that developed with their use were due to operator inexperience with the drive mechanism, which is less sturdy than that of a dragline. Such problems should be greatly lessened with use in removing soft coal.

5) The inventory costs of large draglines is becoming an increasing burden, but no company survey had attempted an accurate costing of its inventory policy.

6) The 75-cubic-yard dragline bucket is considered by most respondents to be the optimal trade-off between size, maintenance costs, and the increased costs of down-time of larger equipment.

7) Seam depth presents no technical obstacles to exploitation, in the opinion of the respondents. Boom length cannot reasonably be expected to exceed 150 feet, so deeper penetration will require multiple movements of the overburden. These will be acceptable if economically feasible.

8) The truck size that presents the best trade-off between size and cost of down-time is the 170-ton model.

9) Shovels are much preferred for coal removal, as they produce 95% of the time, as opposed to a loader's availability of 75%. Loaders will continue to be used at smaller mines with less capitalization.

10) Continuous transport of overburden or coal will be looked at very carefully by any mine operator. It is not anticipated to be installed in the foreseeable future. Any project to introduce such haulage will have to be extremely well demonstrated.

Decision-Making

1) It is important to have any equipment reliably demonstrated in at least three locations before widespread adoption in the industry can be expected.

2) Strategic planning and forecasting of markets and future investment climates is not a part of any company's planning posture.

3) Decision-making procedures in every interviewed company vary considerably as the price of the potential purchase increases. The costs at which the decision-making process changes vary widely from company to company. Generally, surface mining operators allow more latitude to the lower echelons.

4) Most operators queried choose equipment on the basis of the service received from local distributors, as opposed to the reputation of the manufacturing concern. The level of service from local distributors frequently outweighs actual evaluation of the intrinsic values of opposing equipment models.

5) Financial evaluation of purchases is done by all the interviewed companies; these ranged from formalized cash

flows to estimates of payback periods. The results were universally ignored, either because a management decision had been made to proceed with the purchase, or because money was available and alternate areas of commitment were not studied.

6) The major unknown in any purchase decision is the eventual maintenance cost of equipment. Under present contractual agreements, other costs and cash inflows can be readily estimated. As the major component of risk, these maintenance costs have come under greater scrutiny in recent years. One company with about an even split between underground and small-scale surface operations estimated that after five years, trade-in becomes the best option. Rebuilding of mining equipment was rejected by all respondents as an economically rational decision. Cash-flow problems do, however, necessitate it on occasion.

7) Government and industrial predictions of coal use are discounted greatly by traditional coal operators. Such predictions are, however, somewhat accepted by companies that have recently entered the industry. The former companies will proceed in mine development only with definite contractual agreements. The newer companies are more willing to enter without such assurance.

8) Several novel methods are emerging for financial backing. One company acts essentially as an operating agency for the utilities that eventually consume the coal. Another company has developed an organization in which it acts as a marketing agent and technical assistant for small producers.

9) Compatibility of equipment within a company is not a goal of any operator, although it is pressed for by maintenance personnel. In surface mining, compatibility within a single mine is sought, but not to the degree for which underground operators aim.

10) All operators questioned believe that there is a role for government research in mining, but feel it should be confined to exploration of new techniques and not be extended to development of specific equipment.

11) Careful costing of down-time is never done. As it and the related maintenance costs are the major risks in operations, a system to actually cost down-time would be an extremely beneficial selling tool. Such a costing has been done by one large producer of earth-moving equipment. It has proved to be effective in making presentations to potential customers.

12) Introduction of costing of down-time and other factors will be the best way to present equipment favorably to operators. Although they do not do such costing themselves, they are willing to rely on it when it is carefully presented.

1. PURPOSES AND OBJECTIVES

Since 1969, there has been a persistent decline in the productivity of the coal mining industry. Output per man-day for underground mines peaked at 15.6 tons in 1969 and had rapidly decreased to 8.5 tons by 1976.

Various factors have contributed to this decline; while it is difficult to relate any part of the loss in productivity to any one direct cause, interest has grown in the development of more productive mining equipment as a means of reversing the trend. This study is an analysis of mining equipment needs, the developmental process used in manufacturing innovative equipment, and the systems mine operators use to evaluate new equipment purchases.

1.1 INVESTIGATION OF MINING COMPANIES

Mine operators must use a process of selection and evaluation whenever any purchase decision is made. This can range from a cursory perusal of available equipment to a detailed financial analysis of the impact the new equipment will have on profitability. It is this evaluation process, with its attendant variation from company to company, that this study will describe.

Each mining company also faces different geological, financial, historical, and labor constraints. All these color the perception of equipment needs. Desirable types of equipment vary as much as company types. This study will analyze equipment needs and describe the relationship between buyer and seller in both actual and desired situations.

1.2 INVESTIGATION OF EQUIPMENT MANUFACTURERS

Any manufacturing concern must be aware of the impact of a new product line on its overall financial health. This study has examined the process used by several types of manufacturing companies both to evaluate financial impact and to direct research and development efforts.

1.3 EXPECTED BENEFITS TO THE DEPARTMENT OF ENERGY

The ultimate purpose of this study is to describe decision-making processes and perceptions of equipment needs to clarify beneficial ways of fostering the adoption of more productive equipment. By describing financial analysis and decision-making processes, least-cost methods of encouraging increased investment in new equipment will become evident. And, by describing equipment desired by the industry, it will be possible to delineate those areas where research and development would most likely lead to commercially viable products. Both these aims should assure that any resources committed to increasing coal mining productivity be spent in the most efficient way.

2. METHODOLOGY

The input for this report comes from intensive interviews with ten companies which either mine coal or produce coal-mining equipment. This report should in no way be thought of as being representative of the entire coal industry. Instead, it consists of case studies of various types of companies. In the sense that companies that operate in similar environments tend to act in similar manners, these case studies may or may not be representative of situations at analogous companies. Any inferences drawn should, however, be tempered by the awareness that a coal mining concern operating under radically different circumstances will have an organization commensurately different from those described in this study.

2.1 DESCRIPTION OF POPULATION

The attempt to allow inferences by analogy necessitated drawing interviews from as broad a spectrum of companies as possible. In this way, any operating company may be, in some way, compared to its analogous case study. The effort to cover a broad area of the mining and equipment manufacturing industry does not mean, however, that universal coverage is possible. Instead, an effort is made to concentrate on those publicly held companies most prominent in their area.

2.1.1 Mining Companies

The total population of U.S. coal mining concerns was divided by five criteria:

- o Geographical location (Western or Eastern)
- o Type of mining (surface or underground)
- o Degree of independence (independent or part of a conglomerate)
- o Amount of revenue from coal mining (primary or secondary endeavor)
- o Type of parent company (oil company or utility)

An effort was made to contact at least one company fitting each of the following descriptions:

- o A utility-owned company
- o A company that is part of a large energy conglomerate
- o A company that is part of a large resource extraction concern
- o An Eastern company primarily engaged in underground mining
- o An Eastern company primarily engaged in surface mining
- o A Western company primarily engaged in surface mining

There is much overlapping between these categories, presenting the possibility of including several descriptions in a single interview.

2.1.2 Manufacturing Concerns

The three types of equipment included as subjects in this study were:

- o Surface
- o Underground
- o Processing/Cleaning

Since the number of large firms engaged in manufacturing coal-mining equipment is extremely small, initial interest was in contacting companies dominating their respective fields. No attempt was made to contact the smaller companies.

2.2 CONTACT PROCEDURE

Six coal-mining companies and three equipment-manufacturing concerns were established as the final sample size. The contact procedure is described in Figure 2-1. Initial contact was made by telephone to a large group of potential interviewees. Inclusion in the final contact list was based on the following factors, listed roughly in order of importance:

- o Willingness to cooperate
- o A careful analysis of company type
- o Degree of fit into desirable array of company types in light of already-scheduled interviews

As interviews were arranged, every effort was made to retain the pre-determined mix of company types.

FIGURE 2-1. CONTACT PROCEDURE

2.3 FINAL INTERVIEW LIST

The list of companies that emerged from the contact procedure (Figures 2-2 and 2-3) maintains the six/three split between mine operators and equipment manufacturers. In general, it also provides coverage of all the desired company types, either singularly or in combination.

2.3.1 Mine Operators

Operator A:

This is a large coal company wholly owned by a large Western utility company. Most of its production goes to meet long-term contract commitments in the Mid-West and West, with the remainder used to fulfill its own needs.

During the last reporting year, output was above 10 million tons from mines located mainly in the Eastern Rockies. Operations are totally surface, and large production increases are planned for the near future. Control of operations is heavily centralized.

Operator B:

This company is a recently acquired subsidiary of a much larger resource-extraction and chemical conglomerate with minor oil and gas interests. Sales of the parent company overshadow those of the coal subsidiary. Essentially all of the coal production goes to meet two or three contractual agreements.

During the last reporting year, output was less than 10 million tons, primarily from mines in Eastern Kentucky. Production is about evenly split between surface and

FIGURE 2-2. FINAL CONTACT LIST - MINE OPERATORS

	Production Source	Company Type	Annual Output (In Millions of Tons)	Mine Location
Operator A	Surface	Wholly Owned by Utility Company	More than 10	West
Operator B	Surface/ Underground (50/50)	Subsidiary of Larger Resource- Extraction and Chemical Conglomerate	Less than 10	East
Operator C	Underground	Exclusive Coal Mining Concern	Less than 10	Mid-West
Operator D	Surface	Subsidiary of Large American Oil Company	Less than 10	West/Mid-West
Operator E	Underground	Marketing Agent for Independent Coal Operators	Less than 10	East
Operator F	Surface	Diversified Concern	More than 10	West

FIGURE 2-3. FINAL CONTACT LIST - EQUIPMENT MANUFACTURERS

	Product Line	Company Location
Manufacturer A	<ul style="list-style-type: none"> - Surface Mining Machinery - Construction Machinery - Industrial Products 	Mid-West
Manufacturer B	<ul style="list-style-type: none"> - Underground Mining Equipment - Air Tools - Other General Products 	East
Manufacturer C	<ul style="list-style-type: none"> - General Mining Equipment - Pollution Control Equipment - Commercial Processing Equipment 	West

underground sources; however, most expansion is coming from surface operations working on a bench-cut system. There is a great degree of centralization in operations.

Operator C:

This company is exclusively a coal-mining concern, with virtually no income from other sources. Production during the last reporting year was about 10 million tons. Some of the production is sold under contract, but most is produced for the company, which acts as operating agent for a utility. This is done under a cost-plus contractual arrangement which allows for full recovery of operating costs plus a fixed fee. The contract also allows for auditing procedures by the contracting utility. Operations in Ohio and Pennsylvania are almost exclusively underground. Operations are extremely decentralized, with no line positions in the corporate headquarters.

Operator D:

This company is a subsidiary of one of the largest American oil companies; it was acquired by purchase. Profits from the coal subsidiary are overwhelmed by the other profit centers within the larger organization. During the last reporting year, coal production was about 10 million tons.

Almost all of the production came from surface mines in the West and Mid-West. There is some Eastern underground production, and plans for Western underground operations are under consideration. The geographical spread of operations necessitates a somewhat decentralized control system.

Operator E:

This company, while having some production of its own, is primarily a marketing agent for independent coal operators. It operates several blending and transshipment points from which it ships coal to fulfill its sales contracts. It buys the coal it needs to cover these shipments either from the market at the spot rate or from its clients at contractual rates. The company also performs services such as marketing, equipment purchasing, aid in meeting government requirements, and some engineering for its independent operator clients.

During the last reporting year, shipments by this company totaled less than 10 million tons, with 60 percent of this coming from either company mines or contract mines; the remainder comes from the spot market. This type of organization allows for a great deal of freedom for individual operators.

Operator F:

This company is a resource-extraction concern engaged almost totally in the mining of ferrous and non-ferrous ores and of coal. It also engages in smelting and refining. Its coal income is approximately one-fifth of that from other sources. Its production of coal in the last reporting year was greater than 10 million tons.

Production is overwhelmingly from surface mines in the Mid-West and Wyoming. The nature of this company's operation necessitates an East-West split in operations control. However, within each geographic area, control is centralized.

2.3.2 Equipment Manufacturers

Manufacturer A:

This midwestern company is a producer of large-scale surface-mining machinery. Its business lines include mining machinery, construction machinery, and industrial products. Mining machinery sales, however, are more than double those from all other sources.

Manufacturer B:

This Eastern company is engaged in the manufacture of underground mining equipment, air tools, and other general products. The manufacture of mining equipment is, however, this company's largest single business segment.

Manufacturer C:

This is a Western-based company primarily engaged in the production of pollution control, commercial processing, and mining equipment. Its line of cleaning and processing machinery currently generates only a small part of the total company revenue, although there are plans to further develop the dewatering technology.

2.4 CASE STUDY SURVEY DESIGN

The survey technique chosen for this study did not depend on mass mailing, but instead on in-depth interviews and the results arising from them. As such, the survey cannot be relied upon to lead to statistically valid predictions of industry-wide future behavior.

The interview was divided into two portions (see Figure 2-4) -- one in which the interviewee proceeded in a guided narrative manner through a description of his buying or development process. The other section of the interview was one in which the respondent reacted to various hypothetical investment scenarios, thus allowing a quantification of his opinions.

2.4.1 Guided Narrative Portion

An attempt was made to refrain from imposing too rigid a format on this portion of the interview. Instead, a list of general questions was formulated. All these questions were usually covered in each interview, but not necessarily in the same order. The questionnaire was amended to reflect the type of company being interviewed, with only the core questions being maintained.

2.4.1.1 Elements Common to Both the Surface and Underground Mining Questionnaires (Appendix A, Pages 1A to 4A)

The elements common to both the surface and underground mining questionnaires fall into four general categories (see Figure 2-5):

- o Perception and evaluation of the market
- o Type of vendor company desired
- o Decision-making process used in purchasing
- o Financial evaluation made of the purchase

As can be seen, these questions deal mainly with perceptions of market forces and the evaluation of future performance, considering those factors.

FIGURE 2-4. INTERVIEW METHODOLOGY

FIGURE 2-5. DECISION PROCESS FOR EQUIPMENT PURCHASES

2.4.1.2 Surface Mining Questionnaire Elements (Appendix A, Pages 5A to 7A)

These elements are concerned with the technical aspects of the equipment used to extract coal by surface mining to (see Figure 2-6):

- o Remove overburden
- o Transport topsoil to storage
- o Remove coal
- o Transport coal
- o Replace overburden and topsoil
- o Conform with reclamation regulations

The last item weaves itself through all the others as a constant theme.

2.4.1.3 Underground Mining Questionnaire Elements (Appendix A, Pages 8A to 11A)

These questions, like those for surface mining, concern technical equipment needs (see Figure 2-7). They focus on five areas:

- o Extraction
- o Face haulage
- o Primary haulage

Surface Mining Process

Equipment Required

FIGURE 2-6. SURFACE MINING PROCESS AND TYPE OF EQUIPMENT REQUIRED

Underground Mining Process

Equipment Required

FIGURE 2-7. UNDERGROUND MINING PROCESS AND TYPE OF EQUIPMENT REQUIRED

- o Roof control
- o Health, safety and ventilation

The last item was of importance to mine operators in relation to all the phases of mining.

2.4.1.4 Equipment Manufacturer Questionnaire Elements (Appendix A, Pages 12A to 15A)

The three types of equipment manufacturers polled -- surface, underground, and processing -- were questioned about essentially the same subjects as were the mine operators. Their perception of future purchasing patterns in equipment was covered, the questions differing by the type of equipment sold. However, certain areas were covered which pertain only to manufacturers:

- o Evaluation of the potential market
- o Customer-vendor relationship
- o Types and levels of research and development
- o Evaluation of selling performance
- o Evaluation of the financial impact of new equipment on the company's health
- o Timing of development decisions
- o Marketing the product
- o Experience with joint Federal projects

These questions generally covered the process used to develop and evaluate a new piece of coal-related equipment.

2.4.2 Quantitative Portion

A detailed description of this section is necessary to facilitate the explanation of the analysis. This portion of the interview quantified individual preferences. It should not be thought of as a statistical process which allows generalization from a sample; instead, it is a method of numerically describing an individual's reaction to certain choices.

It was the specific objective of this phase of the study to apply a methodology that would uncover:

1. Which of a set of potential factors seemed to affect major investment decisions
2. The relative importance of the factors which emerged as significant in Step 1, given that all factors would not be equal in impact.

In designing the study, the factors which might impact a coal mining company's investment decisions were divided into two categories -- (1) factors relating to the general economic environment in which the decision would take place; and (2) factors relating to the equipment itself.

2.4.2.1 Factors Characterizing the Economic Climate

A review of literature and preliminary discussions with representatives of the coal mining industry and the Department of Energy resulted in the identification of a host of factors characterizing the economic climate which are thought to be related to equipment investment decisions. Of these, five were selected for intensive investigation.

The five selected factors are:

1. Amount of contracted coal -- It was felt that the greater the amount of coal a mining company had under contract, the greater the likelihood that company would invest in a major new piece of equipment.
2. Certainty concerning the demand for uncontracted coal -- It was felt that the greater the certainty that the uncontracted coal could be sold, the greater the likelihood that a company would be willing to invest in a major new piece of equipment.
3. Unexpected changes in government policy -- In an attempt to improve mining conditions and secure the safety of the miner, certain laws exist which govern the operation of mining equipment. These laws often affect the design of the equipment itself. When a new law becomes effective, it sometimes requires the modification of current operating equipment, and may thus result in considerable unforeseen costs to the mining companies. Because of this, there is a risk factor surrounding the purchase of new equipment. If changes in government policy tend to be a significant inhibitor of new investments, it was felt that a government program to absorb such costs might significantly increase the rate at which new equipment investment takes place.

4. Federal rule-making -- A second factor affecting the risk involved in making equipment investment decisions is the timeliness of information. The sooner a company becomes aware of federal rule changes, the sooner it can incorporate such decisions into its investment policies. If the timeliness of information is important, it would suggest that a new system which provided more information at earlier stages might favorably influence the rate at which new equipment investment takes place.
5. Return needed to cover capital costs -- Two of the factors under government control which affect the return needed to cover capital costs are the rate at which equipment can be depreciated and the investment tax credit. It was felt that the lower the return needed to cover capital costs, the higher the rate of investment might be.

The primary objective of this part of the study was the assessment of the relative importance of each of these five factors in terms of their impact on coal-mining equipment investment decisions.

2.4.2.2 Factors Characterizing the Equipment Itself

Six factors were chosen to describe the equipment itself. These encompassed both direct and indirect attributes of a hypothetical piece of equipment. The six factors were:

1. Per-ton equipment and maintenance costs -- These costs included all direct cash outflows.
2. Recommendation source -- The primary source of information about the equipment.

3. New training required -- The amount of new training required for operators of the new equipment.
4. Control and operation position -- The location of the operator(s) in the normal operation of the equipment.
5. Per-shift production per operator -- The productivity of the equipment in normal operation.
6. Multi-functional equipment -- Whether or not the equipment performs one or two discrete operations.

2.4.2.3 Study Design

Several years of research on choice behavior suggest that the general population is not very adept at introspection for the purpose of estimating the relative importance of various factors when the choice of an alternative involves complex tradeoffs between those factors. In such instances, however, conjoint analysis has been found to be particularly effective at inferring, in a systematic way, relative importance. As a research process, conjoint analysis involves several steps. Its application to this project is described below.

As input, conjoint analysis requires the rank-ordering of several multiattribute profiles. As output, conjoint analysis yields estimates of the relative importance of the various attributes which make up the profiles. In this study, 18 profiles were created by specifying particular levels for the five factors described above. For example, Factor 1 was assigned three levels -- 80 percent under contract, 70 percent under contract, and 60 percent under contract. Factor 2 was

also assigned three levels -- 90 percent certainty, 80 percent certainty, and 70 percent certainty. Factor 3 was assigned two levels -- the status quo (where adverse financial impacts are absorbed by the company), or a government program instigated to absorb such unanticipated financial impacts. Factor 4 was assigned two levels -- implementation of a new system which provides more information at earlier stages, or the present system of information. Finally, Factor 5 was assigned two levels -- either government policy resulting in a 10% decrease in the return needed to cover capital costs, or government policy resulting in a 10 percent increase in the return needed to cover capital costs.

Profiles constitute a description of the economic climate by specifying a specific level for each of the five factors. Subjects were each provided with 18 profiles and asked to rank-order them in terms of their likely impact on a major equipment investment decision. The profile ranked first would be that scenario most likely to result in a major investment in a new piece of equipment. The profile ranked eighteenth would be that scenario least likely to result in a major investment in a new piece of equipment. As an aid in their deliberation, it was suggested to the subjects that they first separate the 18 profiles into three piles and then rank-order the profiles in each pile. In merging the three piles into a final rank-order, they were permitted to switch rankings.

A description of the task instructions is contained in Appendix B. Upon completing the ranking task, subjects were asked to indicate, for each profile, the probability that they would make a major investment decision under the scenario described. Because the conclusions were essentially the same, whether based on the rankings or the probabilities, only the results from the ranking task are used to support the overall summaries below. The derived functions for both dependent variables are described in detail in Appendices C and D.

3. FINDINGS ON EQUIPMENT NEEDS - PROBLEMS AND POSSIBLE SOLUTIONS

Questions on equipment needs for both surface and underground mining were designed to elicit comments indicating either a dissatisfaction with present equipment or a suggestion about desired future trends. In general, the respondents were happy with equipment now in use, but ideas did emerge on where they would like to see equipment changes.

3.1 SURFACE MINING

Since surface mining presents fewer size and height constraints than does underground mining, it is not surprising that equipment for this type of operation was generally found to be more satisfactory than underground equipment. None of the respondents were able to foresee any radical changes in current mining practices; indeed, they could see no reason for such changes, with one exception. New reclamation and safety rules are forcing changes in the degree of precision needed in segregating overburden. In some cases, this has meant more pieces of smaller equipment are required rather than one piece of larger equipment. In other cases, it has necessitated entirely new equipment.

3.1.1 Removing Overburden

In almost all cases, draglines are the method used for the initial excavation. However, in some Western operations having a very low overburden-to-coal ratio, shovel and truck combinations are the preferred choice. In all cases, scrapers are used to remove and segregate topsoil.

3.1.1.1 Manufacturers' Replies

Because the manufacturer questioned (Manufacturer A) is one of the few able to produce large draglines, it has institutional reasons for believing draglines are the preferred method of overburden removal. However, since this opinion is reflected in those of operators, this bias is not harmful. Although the company foresees no decline in the use of draglines, it does anticipate some changes in the type and size ordered.

The respondent has heard from its customers that the largest draglines presently in use are uneconomical in terms of maintenance costs and, more importantly, down-time costs. They have also had some complaints that the large draglines make it difficult to segregate overburden and they have had inquiries suggesting the development of a new model -- a smaller, more maneuverable dragline. So far, no action has been taken on this. The measure of productivity used for draglines is simply up-time, and this has been suffering as the machines get larger. While none of the operating companies has precisely costed down-time, they all realize that the cost is large.

As far as technical problems are concerned, the manufacturing company feels that there is no practicable limit to the size of a dragline bucket, although it sees booms becoming impractical above a length of 150 feet. This means that dragline stripping below approximately 150 feet will always require more than one movement of the overburden. The mine operators did not feel this to be a problem, however. Although the economics of coal price versus mining costs are the overriding factor, the operators believe that stripping can be feasible to 1,000 feet and cite foreign operations where the overburden is already moved three times. They report no problems with the maneuverability of their equipment.

For stripping equipment other than draglines, the interviewed company manufactures two items:

- o Shovels
- o Bucket-Wheel Excavators

Presently, they see no problems and no need to change their shovel design. Despite the checkered history of bucket-wheel excavators in this country, this manufacturer believes that they can be marketed here for lignite mining. The difficulties, they believe, have arisen because operators have attempted to use bucket wheels on consolidated overburden. With hard coal, the approach was too violent for the more delicate bucket wheel, and an overload in the drive train was inevitable. They feel loading lignite will not cause such problems, due to its relative softness. There is also a consensus that lignite operators are presently willing to try bucket-wheel excavators.

3.1.1.2 Mine Operators' Replies

Complaints about draglines were generally of three types:

- o Size
- o Walking ability
- o Down-time

Size of the Dragline

In all three cases, the surface mining respondents claimed that some draglines now in operation were well above

their optimal size. Company A was having the most problems segregating topsoil layers as it is faced with a layer of toxic, highly saline spoil which can not be integrated with other layers. The other two surface mining companies interviewed, while not presently facing problems such as this, could foresee a time when stricter reclamation laws would force more careful segregation of overburden strata. They were therefore looking into the availability of smaller draglines. All three companies found smaller draglines preferable for reasons relating to:

- o Maintenance
- o Inventory size
- o Down-time

The operators are finding it increasingly expensive to carry the inventory necessary for large draglines, but they feel they must, due to the cost of down-time. Inventory pools, while sometimes attempted, do not seem to be an effective solution to the problem.

All three operators seem to agree that a 75 cubic yard bucket is the optimal trade-off between size, maintenance and inventory costs, and up-time. Even with draglines of this size, Operator A felt that 80 percent up-time was the best to be expected.

Walking Ability

There was a consensus that the walking shoes of the larger draglines were overly subject to stress cracks and malfunction. With the expense of one of these shoes held in inventory, this is one of the major concerns of any operator.

Seam Depth

Presently, seams being surface-mined are between 100 and 150 feet deep. However, Operator A is developing a 260-foot deep seam with draglines. All the operators were prepared to go deeper if economically feasible. There were no fears of technical difficulties in exploiting deeper seams requiring more than one movement of the spoil. The 260-foot-deep seam requires that all material be moved twice, but development is continuing.

Shovel Versus Dragline

Operator A feels that investment in a dragline is not worthwhile unless the mine has at least a 15-to-20 year life; otherwise, he would use shovels. That company is operating in the West, where much of the coal is close to the surface and operation with shovels is feasible. Other operators used only draglines and, unless forced by legal requirements, could foresee using nothing else to mine deep coal, although Operator D sometimes removes the final few feet of overburden with shovel and truck combinations.

3.1.2 Transporting Overburden to Storage

Transporting and storing topsoil is a problem when draglines are used. However, when shovel and truck removal is the stripping method, all overburden must be transported to storage as a separate step.

3.1.2.1 Manufacturers' Replies

Although the manufacturer interviewed does not produce large off-highway vehicles, it does have to produce shovels whose bucket size conforms with vehicle capacity. This

manufacturer has not received any negative reports on either trucks or shovels, a satisfaction generally reflected in the industry as a whole. Where complaints are evident is in the area of topsoil removal. As might be expected, the additional cost of topsoil removal, which is a step that was not performed in the past, has been a surprise to operators since the costs have been much larger than anticipated. Although all the operators polled use scrapers for this task, they find the cost extremely burdensome, primarily because of tire wear. There have been some requests from operators that this manufacturer consider developing a smaller dragline for topsoil removal and replacement.

3.1.2.2 Mine Operators' Replies

Operator A is the only one using trucks to any extent in the removal of overburden. The respondent from this company had no negative comments on truck operation. He feels that 170-ton trucks are the maximum size for use in operations. Beyond this size, roadbed requirements for the trucks become prohibitively expensive.

It is in the area of topsoil removal that problems arise. Manufacturer A reported that mine operators are very much concerned about the costs of running scrapers; a major problem is tire wear. Replacement of these tires represents an cost; previously, this problem with tires had arisen only with large trucks. Although some operators claim to have reduced their costs by careful maintenance of roadbed, other equally capable operators find little they can do to minimize tire wear. Despite the perception of a problem, all the operators feel that there is no presently foreseeable alternative to using scrapers to remove topsoil, although, obviously, they would be receptive to any developments.

3.1.3 Removing Coal

Depending on the softness of the coal, the surveyed operators removed it either by ripping or by blasting. Blasting was the preferred method, as ripping exerts extreme stress on equipment. Ripping is also seen as slow and inefficient. Operators have used both front-end loaders and shovels to load coal, but seem to prefer shovels for maintenance and up-time reasons.

3.1.3.1 Manufacturers' Replies

This company (Manufacturer A) does not produce front-end loaders; its experience has been with shovels only. It has had no complaints about the operation or mechanical components of its shovels. The electric shovel, in their opinion, is the best, least-cost solution to coal loading. Ultra-high pressure hydraulics have no place in their plans.

The same satisfaction is seen with the drills they produce. They report few complaints about operations or durability. Complaints about maneuverability of their equipment are also infrequent. Although some operators remove the last few feet of overburden with shovels and not with draglines, this equipment manufacturer would attribute that to a lack of operator skill, and not to inherent problems with dragline operations.

3.1.3.2 Mine Operators' Replies

The operators also seem generally pleased with the equipment they use to remove and load coal. The only areas of possible contention come in a choice between:

- o Ripping or blasting coal

o Loading coal

Ripping or Blasting Coal

Blasting is the preferred alternative, even for those who have rippable coal and who have tried rippers (Operator F). This company rejected rippers as being too inefficient and slow. Especially in the West with its thicker coal, there is no perceived need for improvements in ripping; geological conditions make blasting much more economical.

Loading Coal

Here again, there is a consensus; shovels are much preferred over front-end loaders. Operator A reports that he gets more than 95 percent up-time from his shovels, while he can expect only 75 percent, at the most, from loaders. Even an operator of a small surface mine, Operator B, prefers to use shovels, but turns to loaders because of initial cost constraints. The major problem with loaders, as with scrapers, is tire wear. This problem will become more acute as tire costs escalate. The solution to tire wear, an extremely clean and well-graded pit, is expensive and is not a major concern with shovels.

3.1.4 Transporting Coal

This is a job for trucks in all cases. Some of the mining companies interviewed had tried conveyors and even bucket-wheel excavators. All expressed an interest in a continuous haulage system, but were concerned about its availability. Such a system would have to be very well proven before being commercialized, considering the fears that the operators have about the feasibility of such a system.

3.1.4.1 Manufacturers' Replies

The manufacturers surveyed do not produce coal haulage vehicles; however, they are looking into belt systems and bucket-wheel systems. Operators have been had complaints about the cost of operating large trucks, especially tire and fuel costs. These aspects of truck operation are open to very little improvement. There are not as many complaints about other expense items. The mechanics of large-truck operation are well enough understood that few problems arise with load stress or electric motor operation.

3.1.4.2 Mine Operators' Replies

The problems perceived by the manufacturers, while of genuine concern to operators, are not overwhelming and are not keeping them from using trucks. They are concerned about tire wear, but can see no way to substantially reduce it; they are willing to accept it as an operating cost. The respondent from Operator D had not noted any discontinuity in maintenance costs as trucks increase in size. In fact, although he presently uses 120-ton trucks, he would like to see them bigger. Bigger trucks (170 tons) are currently being used by Operator A. The respondent from that company did not feel that still-larger trucks would be beneficial to him. He can foresee a quantum jump in costs as trucks increase over this size. Also, the cost of down-time begins to be prohibitive in trucks of this size and cost. For this respondent, the preferred alternative is to increase fleet size rather than to increase truck size above 170 tons.

3.1.5 Reclamation

It is here that the most ferment in the industry is arising, because it is here that past practices have had to be

changed most to conform with new Federal and state regulations. Although no great technical leaps have been made in reclamation techniques, surface miners would be more receptive to such developments here than in other aspects of surface mining.

3.1.5.1 Manufacturers' Replies

Although there have been some requests from operators for small draglines to be used in reclamation, the respondent from the manufacturing company does not seem to feel there is a large market for them. He feels that the present use of bulldozers is adequate to the task, even considering more stringent environmental rules. He knows of no company using any other system extensively. The inquiries about smaller draglines are coming from operators who feel that the lack of precision in bulldozing will become an intolerable handicap in future reclamation efforts.

3.1.5.2 Mine Operators' Replies

While all the companies surveyed are presently using scrapers and bulldozers to push spoil back into the pit, Operator A is also using trucks. He faces a problem of highly saline toxic spoil, which has to be segregated and buried at a legally mandated depth. Operator D is presently segregating spoil into three strata for replacement; however, the company has not had to resort to trucks.

There is no great push from operators for manufacturers to improve their reclamation equipment. While there is a general dissatisfaction with the cost of operating scrapers, the use of bulldozers and scrapers is accepted as the least-cost method of reclamation. Operator A would, however, like to see the development of a 20-yard dragline for use in reclamation.

As far as the question of conveyors is concerned, as fuel prices rise and tires become more expensive, operators will apparently come to appreciate their advantage. Operator D seems to feel conveyors might presently be economically justifiable in extremely flat coal deposits such as those in Kansas. Any solution to this increasingly burdensome problem of tire and fuel costs can not be evolutionary, in the opinion of Operator F. It is in this field that highly innovative techniques might be most acceptable.

3.2 UNDERGROUND MINING

Conditions faced by underground mining operators differ to a greater extent than do those faced by surface miners. Seam height, geological conditions, and the general mining environment are radically different from mine to mine. Those surveyed operate many different types of mines, and thus face a variety of conditions.

3.2.1 Extraction

The manufacturer surveyed (Manufacturer B) produces both conventional and continuous mining equipment. Two of the operators are presently using both mining techniques for a variety of reasons, both to maintain an average lump size for processing and to deal with certain conditions of the coal. Depending on the company, seam height varied from extremely low-seam coal to 5- to 6-foot coal. Operators were given a chance in the interview to describe individual conditions they face which they feel are not being handled properly by present equipment.

3.2.1.1 Manufacturers' Replies

Manufacturer B produces conventional and continuous mining equipment, as well as complete long- and short-wall systems. Their concerns for equipment in this area center on:

- o Conventional versus continuous equipment
- o Introduction of long-wall equipment

Conventional Versus Continuous Systems

This manufacturer sells a great deal of conventional equipment -- cutters, drills and loaders. However, the reasons behind purchase of this equipment, in the opinion of the manufacturer, are mainly a need to maintain particle size in processing plants and a desire to obtain large fragments in coal that has a good deal of physical spoil. They have not found any operators turning to conventional mining for purely economic reasons; continuous mining is always more efficient and thus less costly than conventional mining when it can be used. They also have not found that new health and safety rules are pushing operators toward conventional mining. It is much more popular in low-seam, primarily metallurgical, coal where many of the cost benefits of continuous mining are lost. It is in this low- to extremely low-coal that they feel conventional mining has the best chance of expansion.

Introduction of Long-Wall Equipment

There are many producing mines in the East where long-wall equipment can be economically introduced, in the opinion of this manufacturer. There are presently plans under way to develop low-seam, long-wall equipment. The respondent feels that there are no absolute technical barriers to the

development of such equipment. Many of the problems originally faced in repositioning this equipment after completion of a panel have been solved by manufacturing the system in smaller modules. An entire unit is thus easier to move than were the original European models. This has facilitated its introduction into the U.S. mining environment.

Other Considerations

This manufacturer does not believe there is much demand for continuous miners designed with either special bits or slower-speed heads to produce larger coal sizes. They have not had many complaints about fine-coal generation or dust generation. Instead, they see development moving in the direction of long-wall and more efficient continuous miners. Present performance of their equipment is entirely adequate when the miner is in actual production at the face. It is the low level of such productive time (less than 40 percent), and the entire mining sequence, that is of most concern to operators.

Underground augers are no longer produced by this manufacturer. The respondents feel that they are not economically worthwhile. More importantly, present safety rules make their use highly unlikely.

3.2.1.2 Mine Operators' Replies

In general, the operators were satisfied with their extraction equipment. Problems and concerns centered on three areas:

- o Productive time for continuous and long-wall mining

- o Maintenance cost for continuous miners
- o Use of conventional mining and problems with low seams

Productive Time for Continuous and Long-Wall Mining

Two Operators (C and E) use long-wall mining. Another Operator (B) purchased a long-wall system and still owns it, although it is no longer used. The respondent from that company feels that U.S. geological conditions would preclude widespread use of long-wall systems. The two Operators using the equipment were quite satisfied with their long-wall systems in general and plan more installations. All three operators use continuous miners. Problems with productive time are mainly due to the advance and withdrawal techniques of continuous mining system, and not to difficulties with individual pieces of machinery. Technical complaints were rare; however, there did seem to be a definite dislike of physical or hydraulic linkages in mining machinery. Much preferred was a system using an individual electric motor at each point where a drive is necessary. There were few metallurgical problems with the equipment other than a desire for smaller, harder gears.

The present productive time of miners is considered by one Operator (E) to be about 25 percent of the total. This figure is generally acceptable to the other respondents. The consensus is that large improvements in this figure are impossible considering the present face-haulage and roof-control techniques. Long-wall systems offer improvements in productive time, but require a great deal of time to develop a panel and to position the equipment. Operator C is presently having trouble developing panels and can foresee a need for faster, advance mining.

Maintenance Costs for Continuous Miners

Although all operators have had bad experiences with individual pieces of equipment, all three felt that the vendors they purchased from were supplying high-quality products. There are concerns, however, about cost and maintenance. Several of the respondents feel that, while quality is maintained, competition among suppliers is not sufficient to keep costs down. While the level of maintenance support is deemed to be excellent, the maintenance cost per machine is considered high. In part, this is seen as an effect of piecemeal design reactions to governmental safety mandates; the equipment is changing too fast to allow an integrated design which could lessen maintenance costs. There is thus some optimism that the relative value of these costs will lessen as the manufacturers finish reacting to already codified regulations. Operator B is the only company keeping careful maintenance records, and is thus the only one able to make a formal evaluation of maintenance costs of new equipment versus those of old equipment. The company uses these records to decide on trade-in and replacement cycles.

Conventional Mining and the Problems of Low Seams

Operator E (the operator acting as cooperative agent for small producers) and the independent operators producing for him mine areas that have many low seams. The respondent feels that production will continue from these mines and thinks there is a real need for the development of equipment in the 20-to-25 inch range. In these extremely low spaces, a radical departure from existing equipment is needed. He could offer little speculation about what equipment is needed, other than to say that augers would not be the answer. His company uses a great deal of conventional equipment, but only where there is a high percentage of spoil. Their sophisticated cleaning and

mixing plants do not need large-size coal for the proper reaction.

Operator C, on the other hand, also uses conventional mining, but for another reason. The company's present capitalization position does not permit the replacement of antiquated processing plants. These plants cannot operate only on continuously mined coal, but must have a mixture of larger fragments. These larger pieces are provided by conventional mining. The respondent from that company does not, however, advocate conventional mining. The skill levels required are too high for his incoming employees. Also, safety and, especially, ventilation rules are hard to comply with, considering the several stages of work going on simultaneously. Highly specific safety rules almost mandate continuous mining, and he can see no way to change conventional mining techniques so as to comply. He has found it difficult to arrange for the mandated air flow at the loading area while also maintaining the air flow at the area of the face where cutting is underway. From his viewpoint, the difficulties and expense are so great as to push him toward continuous miners.

3.2.2 Face Haulage

The operators surveyed all use shuttle cars for face haulage. This is the primary face haulage equipment line for Manufacturer B, although it is presently developing an advanced conveyor system able to negotiate tight corners. Operator C has had some experience using face conveyors.

3.2.2.1 Manufacturers' Replies

The underground equipment manufacturer is of the opinion that face haulage is the controlling constraint in

production, but it does not stand alone. This respondent was quite emphatic that continuous haulage must be part of a continuous mining system which would also include continuous mining and simultaneous bolting. Until such a system is in place, a drastic increase in productive time is impossible. The manufacturer is presently developing a flexible belt that will be suspended from roof bolts. The problem with this belt system, as with all previous systems, is the belt itself, and not the drive or suspension systems. The ideal belt would flex, yet retain its general shape. There has also been some work on pneumatic and hydraulic systems. This manufacturer feels there is no reason why such systems would not be acceptable, given a sufficient level of technical development.

As for shuttle cars themselves, there is a general level of satisfaction with their operation. There is little room for improvement in the already smoothly working system of loading and unloading. The only problem is the constraint limited car capacity imposes on the continuous miner. This company has done some development of a surge car to handle this problem for an individual mining company. Although the car met all the specifications, it was rejected as being uneconomical for the company that had written the specifications. This led the company to reject surge cars as the solution to the problem of low productive time for continuous miners.

3.2.2.2 Mine Operators' Replies

All three respondents, Operators B, C and E, use only shuttle cars for face haulage. Operator C has had experience with belts in room and pillar mining, but was unable to continue their use as the system could not meet ventilation standards. That company felt that there was no inordinate

problem with maintaining standards for the belts, but found it extremely difficult to keep men in belt-tender positions. The work is extremely difficult and even more physically taxing than other mining jobs. Any attempt to introduce face haulage belts will thus meet with great skepticism from this company.

All three operators were certain that roof control, and not face haulage, was their main constraint. Of all aspects of underground mining, shuttle cars were the most satisfactory, both in performance and in productivity. There was a consensus that the cars could keep pace with production even if improved, faster roof control techniques were introduced and production increased.

3.2.3 Primary Haulage

Primary haulage means, essentially, belt haulage. There are some situations where rail is still being used, but these are becoming fewer and fewer as belts become more reliable and better able to traverse long distances.

3.2.3.1 Manufacturers' Replies

Although Manufacturer B does not produce primary haulage equipment, it does receive feedback from its customers on their needs. Primary haulage systems, like face haulage systems, are easily able to handle the production from continuous miners. So, while belts and rail might not be as efficient as they could be, problems do not arise since they are almost always adequate to the task.

3.2.3.2 Mine Operators' Replies

There was a basic difference of opinion among the respondents, apparently based on the age of mines. Operator E

would not consider using anything other than belts for primary haulage. Operator C, on the other hand, feels that rail transportation is preferred at distances beyond two miles. Obviously, though, with improvements in belts and support systems, rail transportation will have a rapidly decreasing share of primary haulage. The direction is certainly towards continuous primary haulage.

3.2.4 Roof Control

Except in a few, very limited circumstances, roof control is accomplished only by roof bolting. There are no major technical problems with the process itself -- only with the time it takes. And while bolting is expensive, it is the most economical solution to roof control.

3.2.4.1 Manufacturers' Replies

Manufacturer B has a commercially available miner bolter. It can see no widespread use of this equipment, however, until continuous face haulage is available to cope with continuous production. With present face haulage, the respondent feels that a less automated system, rather than a fully automatic bolting system, would be the preferred alternative. Since haulage is the constraint, it would be useless to automate the extraction and bolting process beyond a level with which shuttle cars could cope. Some manufacturers feel that in extremely high coal, the larger shuttle cars will be able to carry enough coal away from the face to allow truly continuous extraction. They feel that a system that is very much like conventional bolting, but which does not require withdrawing the miner, is sufficient to the task.

The health and safety problem associated with the drilling for and placement of bolts have been adequately solved, in the opinion of this respondent. Automatic placement of the bolter and ventilating drill stems have removed the two most pressing health and safety hazards.

Problems with bolting, other than its causing the retreat of the continuous miner, are predominantly in four areas:

- o Fissile roofs
- o Slowness in drilling
- o Cost of bolting
- o Bolting in low seams

The problem with bad roofs can be solved with resin bolting and with longer bolts. There seems to be little that can be done about the slowness of drilling, other than to drill several holes simultaneously and to progress to a highly automated miner-bolter. While there are innovative ideas in hollow, expandable bolts, the costs of these remain high. According to this equipment manufacturer, cost is the major complaint of operators, and much remains to be done to reduce it. As for new developments, they should come in some type of flexible bolt for low-seam coal. It is here that the bolting process is least effective and most costly.

3.2.4.2 Mine Operators Replies

Mine operators are very much concerned about roof bolting and its attendant delays. All agree that this operation is the major constraint on their production. The

solution of a miner-bolter is the obvious one, but there is natural hesitation to commit the company to such a sophisticated piece of equipment. Operator C has found the automated temporary roof support to be a good interim solution. It allows remote-control placement of the bolter and of roof supports; old bolters can be adapted to this mode for less than \$10,000. Of course, the problems of drilling individual holes and placing single bolts remain.

The problem of bolt placement has a possible solution in using the bolt to form the hole, rather than using a drill. In a sense, the bolt would be "shot" into the roof.

3.2.5 Health, Safety and Ventilation

This aspect of coal mining impacts all others. Concerns center on four major areas:

- o New safety procedures
- o Dust control and ventilation
- o Noise control
- o Ancillary safety equipment

3.2.5.1 Manufacturers' Replies

The surveyed manufacturer has very definite opinions on all four of the major areas of concern. While the respondent feels that it is able to understand Federal rules and respond adequately to them, it feels that the iterative nature of the rules precluded a total engineering approach to design. Lights were cited as an example of the problem; they

have had to be attached to already designed equipment and are thus prone to damage. The net result is to make the equipment more complex than it otherwise need have been.

New Safety Procedures

The procedural rule having the most impact on equipment and mining procedures is the 20-foot advance rule. This has meant a rethinking of the entire continuous mining process and has made the miner-bolter a more attractive alternative; it has made its successful development almost a certainty if underground mining is to remain economically feasible. However, this manufacturer sees a system of truly continuous mining as needing the support of truly continuous haulage.

Advance rules have also meant a decline in the amount of conventional mining, as it becomes impossible to coordinate the movements of the separate work gangs in a conventional sector. As processing plants are modernized, the need for large-lump coal will decrease. If a better method of mining low-seam coal is developed, conventional mining will decline even further.

Dust Control and Ventilation

In the opinion of this manufacturer, very explicit ventilation rules have lessened his incentive to produce low-dust-generation equipment. Since regulations are written to specify not only dust level, but also air flow, there is no need to change equipment to generate less dust; the mandated air flow ensures an acceptable particulate level. The same is true of gas generation. So, while some work has been done to produce low-dust-generation miners, this has not been of great interest; such an investment would not lessen the ventilation costs and strictures faced by the mine operator.

Ventilation rules have also made it much more difficult to maintain the separate work stations necessitated by conventional mining. Mandated air flows are extremely difficult to maintain when workers occupy more than one area. The manufacturer prefers to use dust controls to keep dust levels acceptable, rather than to use equipment that generates less dust.

Noise Control

Proposed noise standards for underground mining are so strict, in the opinion of this manufacturer, that they will be impossible to comply with. Although the general content of these rules is presently known, the manufacturer is not designing equipment to comply, in the belief that the rules must be changed before final promulgation. Thus, new noise rules have not yet affected equipment design.

3.2.5.2 Mine Operators' Replies

Operators' concerns center on the same four major areas as those of the manufacturer. In general, the operators agree with the manufacturers that new health and safety rules encourage some techniques and equipment, but discourage others.

Ancillary Safety Equipment

Safety equipment is not as great a concern to the mine operators as design is to the manufacturer. Frequently, however, there are problems in gaining miners' acceptance of the equipment. The miners' reluctance vis-a-vis safety equipment is stronger than the usual skepticism about new techniques and equipment. And it is here that the greatest criticism of manufacturers emerged. As equipment has had to be rapidly changed to meet a changing regulatory environment,

ancillary equipment (canopies were the most frequently mentioned) has been added to equipment not designed to carry such options. Clearances have suffered, but, more importantly, the equipment has frequently become unwieldy from a human engineering standpoint. Sightlines and control position have deteriorated. There is thus an agreement with the manufacturers that a holistic approach to design would be better; this would require promulgation of rules and regulations as a body.

New Safety Procedures

There is a consensus that safety regulations have meant the eventual decline and disappearance of widespread conventional mining. While other factors exist, new rules are apparently the major reason behind the decline. The interviewees could think of no other way in which new safety procedures have caused major changes in equipment type, although the mining process itself has been greatly affected.

Dust Control and Ventilation

Dust control and ventilation regulations have had a major effect on the type of equipment purchased. Although modifications to existing equipment have been limited, entirely new equipment has had to be purchased. There is concern about the larger fans and increasing support equipment needed to maintain a proper air flow. This is becoming more of an expense than originally anticipated, and new methods of delivering air to the work force would be greatly welcomed. As was the case with scrapers in surface mining, purchase of a new category of equipment has proved to be a major undertaking, even though it was not originally anticipated to be such.

Operator C can foresee a time when operations in all mines will have to be fully compartmentalized. This will mean additional equipment and some changes in present equipment and procedures. Exactly how these changes will evolve is not yet certain. This respondent also feels strongly that rules should be more performance-oriented. He feels constrained in trying innovative approaches to lessening dust exposure. The lack of interest in low-dust-generating continuous miners is one example of this. He does not feel that he would have much trouble keeping dust exposure down with administrative and other low-cost means, and thus considerably lessening his equipment costs. He also considers regulatory barriers as his main hindrance to these low-cost solutions; labor approval would be a negotiable item, but would eventually emerge, in his opinion.

Noise Control

There is very little concern for noise control among mine operators. The new rules are considered unenforceable and, as with many other regulatory matters, the operators do not plan for eventualities. Their predictions on the direction of regulation have been incorrect so frequently in the past that attempts at prediction are seldom made. Eventual noise rules are a great concern, but no actions are presently being taken to meet possible standards.

3.3 CLEANING AND PROCESSING

There is a vague consensus that coal purchasers will begin to demand delivery of a cleaner, more uniform product. The extent of this push for higher quality is not yet clear. Obviously, it is not strong yet, as most of the respondents have not had direct demands placed on them.

3.3.1 Manufacturers' Replies

This processing equipment manufacturer (Manufacturer C) has a diversified product line and produces underground mining equipment as well as processing plants. His perception of the market for processing plants is not bullish, so more corporate resources are going into the development of coal and hard-rock mining equipment. Presently Manufacturer C's activities are mainly concerned with coal washing and physical cleaning. The equipment is adequate to the task of processing continuously mined coal.

3.3.2 Mine Operators' Replies

Operator E, the cooperative agent, has developed the most sophisticated processing equipment of any of the respondents. This company physically cleans 100 percent of its output. As this concern subcontracts most of its production, it must also have sophisticated mixing facilities which allow it to load anything from steam to metallurgical coal from the same stockpiles. They are already doing customizing work for their ultimate consumers. The interviewee can foresee further demands for chemical as well as physical cleaning. He believes the coal consumers will have the influence in the market to demand chemical cleaning from future coal producers.

Operator C does not process as much of its total production as does Operator E; however, the respondent experiences some problems processing the fine coal which results from continuous mining. They have thus had to mix conventionally mined coal into the input. The interviewee realizes that its present, antiquated processing plants would soon not be able to meet environmental standards, but felt that the plants could be modified to continue just physical cleaning and still exceed effluent standards. None of the surface mining companies does any processing other than washing.

4. DECISION-MAKING IN MINING COMPANIES

The decision of a mine operator to buy any particular piece of equipment has four steps:

- o Who must decide on purchase?
- o Is the equipment needed for production?
- o Which vendor company is best for this equipment?
- o Will the purchase be advantageous for this company?

It is only by examining all four of these aspects that an understanding of mine operators' purchasing processes can be gained.

Internal organization and decision-making steps differ so radically among the interviewed companies that little communality is obvious. Each operating company has an extremely distinctive command chain, so each will be discussed separately.

4.1 OPERATOR A

This company has centralized staff positions, although operational control is at the individual mine level. Purchase decisions tend to be made at the corporate headquarters. As part of a utility group, this operating company has supervision from the parent group. The interviewee was the Vice-President of Mining Operations.

4.1.1 Equipment Decision-Makers

Generally, the mine supervisor initiates a request for equipment. The request is then referred to a staff level, where the engineering department does an analysis of mine type and the equipment requested. At this point, the most important input is added -- other mining firms using the same equipment are contacted. The staff level review is more formal than most in other companies, in that an engineering analysis is actually done to determine whether or not the mine supervisor has chosen the appropriate equipment. Although this analysis is not cursory, the supervisor usually receives the equipment he requested providing he remains within his budget. This is typical of mining operations; a mine supervisor will almost never have equipment forced upon him, since his good-will is so important.

As would be expected, equipment costs play an important part in determining decisions. There are two definite discontinuities in this company on the scale of increasing equipment costs:

- o The respondent cannot sign for purchases above \$500,000 unless the purchase is specifically provided for in the budget.
- o Equipment purchases above \$750,000 are considered to be major capital purchases and are therefore of interest to the board and parent company. An individual lifetime cash flow is done for these purchases.

A budgeting committee meets to set a cost limit for major capital purchases. The operating and purchasing departments then select the actual equipment. A purchase order

is adequate for equipment costing up to about \$300,000. Purchases in excess of this amount require a contract.

4.1.2 Determining Equipment Requirements

The evaluation of the market for coal in this company is complicated by the leases that it holds on Federal lands. As part of the good-faith provisions, these lands must be developed. This requires the operator to start production without having all the output committed under contracts; however, the company requires that some of the coal be contracted, so mining is never purely speculative.

The estimation of the future market for Western coal is nearly impossible, according to this respondent. One indication of this is the lack of strategic planning by the company. Future markets and the company's share of those markets are much too uncertain to allow present actions to be based on prediction. Present events drive company policy, and can be reduced to two questions: Is a contract for the coal signed, and can leases be maintained? In the opinion of the interviewee, Federal lease provisions are driving production so high that coal is now being sold below cost. This is one detriment to equipment investment. A major uncertainty remains, however, as to the direction in which clean-air rules will drive production. The respondent has little idea of Western coal's place in the future market; so, although convinced of increasing coal consumption, market uncertainty makes him wary of new investment.

4.1.3 Choosing a Vendor Company

Vendor companies are kept on a bidders' list and asked to submit bids on new equipment. The bidders' list is re-evaluated and sometimes amended, although as a surface

mining concern, this company has few vendors from which to elicit bids. The aspects of any vendor company by this operator are, in order of importance:

- o Local distribution organization
- o Cost of equipment
- o Company background

The local distribution organization of a national equipment manufacturer is frequently the sole contact available to an operator after a sale. This interviewee bases most of his decisions on new equipment on the quality of the local organization. This is measured by the level of service and the speed with which the local organization supplies parts. The reputation of the local representative far outweighs the reputation of the manufacturer itself.

This respondent was more willing to admit that equipment cost is important to him than were other equipment purchasers. He felt very limited in the number of companies he could solicit; all of those companies could supply equipment sufficient to his needs. He therefore used price as his guideline if he was nearly equally satisfied with the local service representative of the competing bidders. As part of a utility company, this organization enjoyed unique accounting and financing alternatives and constraints. This makes financial considerations different for this concern than they are for other, less regulated companies.

The vendor company's background is important to this interviewee. To a greater degree than most respondents, he is unwilling to purchase from a new company, perhaps because he is well satisfied with the performance of his present vendors. He

is convinced of their good faith in his dealings with them. One basis of his acceptance of new equipment is a survey of the number of pieces of that equipment being used in this country, although he has bought equipment from Britain and Germany. He is most interested in the present customers of any vendor company. He feels he must be absolutely sure that any provider of large equipment will stay in business for at least 30 years; however, this is not an apparent problem with any of his present vendors. He also feels that competition in the industry is sufficient to keep costs down and quality high.

4.1.4 Financial Evaluation

The equipment purchased by this company is evaluated in terms of its contribution to the mine. The mine, in turn, is evaluated on its impact on the company's financial health. There is never any thought of moving equipment from mine to mine. A cash flow analysis is performed for purchases above \$250,000. Because they are part of a utility, tax benefits accruing from capital investment are not important to them. The parent company cannot use its present Investment Tax Credits and depreciation write-offs to their full extent; it needs no others. Thus, this coal company owns very little equipment outright. Instead, it uses leveraged leasing contracts which allow the coal company to purchase equipment, finance it (usually internally), and then sell it to a leasing company, which in turn leases it back to them. As the leasing company receives all the tax benefits of ownership, the effective rates for these leases are very low. Thus, tax-related inducements for investment would have little effect on this concern. Inducements from manufacturers are limited to total cost and the scheduling of periodic payments required during construction of draglines.

This operator has had several management techniques imposed on it since its recent acquisition by a large chemical and mining concern. As part of these changes, a more careful financial analysis has emerged. Also under development is a computerized maintenance record for each major piece of equipment, used to indicate the point at which maintenance costs begin to exceed the costs of a trade-in. The company has found this situation occurring much sooner than expected in the equipment's life-cycle, sometimes within five years of the initial purchase date. The interviewee is the Director of Purchasing.

4.2.1 Equipment Decision-Makers

This company has a very formal budgeting procedure consisting of seven steps:

- 1) A contract is signed to sell coal and a yearly output is set for the mine.
- 2) The amount of equipment needed is determined by the mine supervisor and engineering staff.
- 3) The financial department develops a budget and presents it to purchasing.
- 4) Purchasing sends out solicitations for bids based on budget and equipment requirements.
- 5) Bids are received and the specifications are reviewed by financial staff, operations, and especially by maintenance personnel.

- 6) A consensus is reached, usually deferring to operations.
- 7) A cash flow analysis is performed, based on input from all three departments in Step 5.

Purchases below \$50,000 are not acted upon by the interviewee and are treated as routine. Those between \$50,000 and \$200,000 are treated as normal purchases, but require his review. Purchases above \$200,000 are considered to be major ones and require more evaluation, while those above \$2 million require approval by an Executive Vice-President.

4.2.2 Determining Equipment Requirements

The perception of the coal market for this company is colored by its ability to produce low-sulfur Eastern coal. The demand for this product is higher than the demand for other types of coal. Its ultimate market is most dependent on TVA electrical production. Although the TVA's prediction of an 11-to-12 percent increase in coal usage is apparently too optimistic, this coal operation still finds the Authority's prediction of better quality than predictions from other government entities. This respondent claimed that his company produces only for contract, a fact generally true for new mine openings. The company's production, however, exceeds contractual obligations. It is apparent that some of this over-capacity has resulted from a belief in governmental prediction. The resulting over-capacity has made the company extremely wary of making investments other than those absolutely necessary to maintain contractual deliveries.

4.2.3 Choosing a Vendor Company

This purchasing officer has a view remarkably like the operations chief who responded for Operator A. Their views are almost interchangeable, even to the desire to use present bidders exclusively. If there is a difference, it is in two areas:

- o Importance of maintenance staff
- o View of competition

This operator has developed sophisticated techniques to control maintenance cost. These costs are the major unknown risks in buying a piece of equipment. This operator asks for formal input from his maintenance staff before purchase. In most other operating companies, maintenance input is not formalized, and concern about such costs arises only through of a concern about down-time.

While this respondent is generally satisfied with the level of competition in slack times, he felt that the rush for equipment in 1974, with the resultant rise in prices, is sufficient proof of under-capacity in the industry. Even now, he feels that price levels escalate much faster than would be the case in an industry with more competition.

4.2.4 Financial Evaluation

Unlike decision-makers in other mining organizations, this respondent is aware of the inputs to his cash flow analysis, knows of the results, and uses them in his purchasing decisions. The basic inputs of the cash flow method are imposed by the parent company:

- o Ten-year discounting period
- o Discounting factor from the parent reflecting the cost of credit
- o Longer discounting periods used informally for large equipment

There have been instances when equipment requests have been refused if the cash flow was negative. This is an unheard-of occurrence at other companies.

Since the company purchases all its equipment, tax benefits accruing from the Investment Tax Credit and depreciation charges are included in the cash flow. The accounting method used is standard.

4.3 OPERATOR C

This operator is extremely decentralized. Staff positions at headquarters are very few. Almost all purchases (including purchases of long-wall equipment) are made at the division level. The head of the division assumes both operations and staff functions. This has the effect of tending to divorce the operations and financial sides of the business. Interviews were conducted with the President of one division and with the Vice-President of Underground Mining at the staff level.

4.3.1 Equipment Decision-Makers

Purchasing is relegated to a lower decision-making position in this company than it is in others. Bids and specifications are solicited and received by the engineering

department and a decision is made on the model desired. Purchasing is then directed to order the selected piece of equipment. The purchasing department provides only clerical support and does not even perform the mediating role given to it at other companies. There have been very few instances where purchase decisions have been overridden by the corporate staff, although it does enter the budgeting process.

The budgeting process is rather straightforward. In September, a budget meeting is held at the corporate headquarters, where one-year and five-year projections of needs are made. Depending on cash position, the budgeted money is released quarterly. Thus, unlike other companies, even when a piece of equipment has a place in the budget, it cannot be purchased at just any time during the year. The five-year projections is an innovation whose worth is not yet proved. In an effort to obtain further knowledge of financial impact, a life-of-mine study has been instituted. Whether or not the results will be used is not yet clear, since the process is so new.

The unique financing used by this company also necessitates another level of review. Its system of essentially acting as an operating manager under a cost-plus contract from utility companies naturally means that those utilities will closely oversee the mining operations. In most cases, this review is solely through auditing. In some cases, however, the utility has entered the capital budgeting process. More of this kind of action is expected in the future. The utilities have intervened at a \$10,000 investment level.

It is interesting to note that the perception of the budgeting process is the same from both the operations and staff levels. The process is well understood, despite the noticeable lack of oversight from the home office.

4.3.2 Determining Equipment Requirements

As most of this company's production is high-sulfur coal, their expectations of market prospects are somewhat pessimistic. All recent production increases have been made under the cost-plus management contracts with utilities. These are usually for coal owned by this operator, but the utility assumes all financial responsibility. The operator is reimbursed for the coal delivered on an unlimited cost-plus basis. This removes almost all uncertainty from the operator's financial planning. The respondent is convinced the long-term health of his company is assured as the nation is forced to turn to coal. The short-term prospects are assured by the company's contractual agreements with the utilities. Overall, they feel in a safe position. They face very little uncertainty and do few projections. They know exactly how much equipment they need and, as they are insulated from operational losses; they are not as careful as others in making equipment purchase decisions.

The company operates some mines on its own through the parent company. Prospects for these are not as good; some are losing money, even though the coal is contracted. Prospects for this production are so bad that there are no present plans to expand it. The quarterly cash disbursements frequently pass over these company mines; they are not profitable enough to warrant any investment.

4.3.3 Choosing a Vendor Company

This respondent, the operations president, is very certain of the equipment he purchases. He seemed to accept the present limited number of vendor companies as sufficient for his needs. He finds no troubles with local service representatives. Since his operations are in the center of

traditional coal territory, they are the most heavily serviced of any in the country. All the vendor companies have developed extremely dense networks of service offices and parts warehouses in this area. The respondent feels he must hold a \$2 million inventory for every 300,000 tons of production; consequently, the availability of parts is extremely important to him.

The interviewee is prepared to accept slowness in delivery and some other negative points in his general positive outlook on vendors. Like other respondents, he is convinced of their genuine good-will in helping with problems. Presently, there are no thoughts of going outside the present bidders' list except for special equipment. The company purchased from German and British vendors for long-wall components.

The respondent does have a very serious problem with one aspect of his equipment. While satisfied with service and quality, he felt that competition is not sufficient to produce enough options for him to choose from. Thus, he feels human engineering aspects of the equipment suffer. He is certain that the vendors should work more closely with operators and that such a process would ensure equipment better suited to his needs. As much of his coal is low-seam, the trouble he faces are probably due to the lack of progress in engineering truly low-seam continuous miners.

4.3.4 Financial Evaluation

This company's financial situation, it works under cost-plus management contracts, allows it great freedom from many of the usual financial constraints. Budgeting and disbursement are decentralized, with the quarterly allowance being spent as the divisional chief wishes. An informal payback-period analysis is done at the divisional level, which is complete in that it accounts for:

- o Labor savings
- o Cost of money
- o Cost of maintenance

The maintenance records are beginning to be computerized. Like many other coal companies, this one has realized that maintenance costs represent the greatest unknown in the operations; as such, it is the problem to be attacked first. As the company estimates the rebuild cost of equipment to be about 66 percent of the new cost, increased maintenance costs for a piece of equipment usually lead to a purchase rather than a recapitalized rebuilding.

Financing comes through the immense borrowing power of the utilities. They either guarantee loans to Operator C or provide capital funds directly. Either way, funding of equipment for these contract mines is no problem; however, capital acquisition for corporate mines has been deferred due to a poor cash position.

4.4 OPERATOR D

This operator is in the position of being a subsidiary of a large American energy company. As such, it has access to almost unlimited financing, but also faces close supervision by the parent company. The coal company is geographically dispersed and is organized on a divisional basis. However, it is subject to close financial supervision from headquarters. As is the case for all coal companies, operational decisions are extremely local. The director of Purchasing and the Vice-President of Operations were the respondents.

4.4.1 Equipment Decision-Makers

The control exerted on the divisional level is indicated by the low level of local action allowed. Purchases above \$50,000 must be reviewed in coal division's corporate headquarters. There is also a formal budgeting procedure for continuing operations. In June, the annual budget meeting is held, with corporate staff, divisional managers, and individual mine managers in attendance. There is also a formal review of the past year's performance. The process is much more team-oriented than with other mining companies, a system apparently imposed by the energy parent. However, there appears to be a consensus that the approach is beneficial. This budgeting process typically proceeds in four steps:

- o The individual mine superintendents present a package of their needs. This package has already been approved by the divisional manager at a local meeting.
- o The overall company package is ironed out at meetings and in corporate staff meetings.
- o The package is presented to the corporate parent, although financing is sometimes done by the coal company.
- o The parent company evaluates the package, using its standard financial evaluation tools, and decides on how much more money to commit.

Control from the corporate parent is strictly budgetary. There has never been an attempt to inject opinion as to the actual operation of the coal company.

Despite the apparent sophistication of this entire process, the divisional manager is still the deciding factor in purchasing decisions. This is almost universal in the industry. However, the divisional manager's influence is greatly limited in the purchase of large equipment, draglines and shovels. Decisions on this equipment are made at the corporate level. In other companies, even these decisions would be divisional, although with strict review.

4.4.2 Determining Equipment Requirements

This company engages in more strategic planning than do others. However, few actual decisions are based on the results. The market for coal is so dependent on non-market factors that the management is unwilling to base its actions solely on predictions. It is committed to expanding production, although not presently engaged in doing so.

Despite its disclaimer about basing action on prediction, the company expands production without definite contracts, and does this to a much greater extent than any other interviewed coal concern. The company is willing to open a mine with only 80 percent of the initial production committed. But since it is willing to develop a mine initially with only a small proportion of its ultimate equipment, the life-of-mine production is only minimally covered. This action is bold for the coal industry. Again, it is probably a directive from the corporate parent, which, in a cash-rich position, is willing to gamble on an increasingly large coal market or on financial benefits accruing from investment in mining equipment.

4.4.3 Choosing a Vendor Company

As is the case with most surface mining companies, this one is well satisfied with the equipment it uses. What is interesting about its approach to vendors is its willingness to accept equipment from new, small manufacturers. This is one more aspect of its willingness to gamble on the future. Also, as is the case with all mining companies, this company demands service above all else. This had not been a problem in the past, even with the small suppliers.

The approach to new products and small vendors is much more formal than with other companies. The products are evaluated by the engineering staff and, typically, a short-term lease is arranged if the evaluation proves satisfactory. New companies do not manufacture draglines, but instead supply ancillary equipment, much of which is newly required as a result of federal safety rules. An example of such ancillary equipment is air conditioners. If air conditioners go down, then a closed cab is uninhabitable and the equipment must be shut down so as not to violate health and safety rules. Yet this company has not been able to locate a suitably reliable air conditioning system. Because of this supply problem, management is willing to go to small suppliers for bids. Purchases of drills have also been made from small, struggling companies. The only demand made from the small companies is for levels of service and good-will comparable to that currently received from larger companies. The respondents do not demand the same level of financial stability in their vendors as do smaller coal companies. They have also shopped outside this country for small equipment, such as Japanese bulldozers. This is the only interviewed company to engage in overseas purchasing of this nature.

Existing competition, as opposed to what existed in 1974, is enough to get good equipment delivered within a reasonable length of time, although there were complaints of lateness. The respondents also feel that the companies from which they solicit bids are sufficiently motivated to offer new equipment or to compete on the basis of customized packages.

4.4.4 Financial Evaluation

Although this operator uses the most sophisticated financial analysis of any company interviewed, it probably pays the least attention to the results. Cash flow analyses are done by both the operator and the parent energy company. The parent is so cash-rich, however, that its cost of money and the drawbacks of risk are considerably lessened. Thus, some projects that the coal company has rejected as being economically unsound are later funded by the parent, which uses much freer standards. Consequently, almost any project can be justified.

The most innovative aspect of the cash flow analyses is the inclusion of specific time-and-motion studies for large equipment. Precise cycle times are used to estimate productivity. This is a much more scientific approach than the approach generally used in the industry -- an approach which measures only up-time.

This company is characterized by a precise, scientific approach to equipment evaluation and financial evaluation. However, these evaluations are frequently superfluous, since funding comes from the corporate parent and is often made despite the results of the evaluation. This company labors under few of the financial and economic constraints weighing down other operators.

This operator essentially acts as a profit-making cooperative agency for independent operators. It provides financing, coal marketing and other services. It sees itself as the wave of the future, and its organization as the only method of survival open to independent operators. Although it does operate some of its own mines, these form a minority input into coal sales. The bulk is either bought from independents on the spot market or under contracts. The respondent from this company was the General Manager of Purchasing.

4.5.1 Equipment Decision-Makers

The independent contractors decide on required equipment. The company then assists them in financing. There is usually not much done by the company to change the contractors' choices. But, as the company is ultimately interested in the financial health of these independents, the equipment requests will occasionally be changed or refused. The company's supervisory staff is small, and a consensus decision is possible. As there are two profit centers -- the company and the contractor -- financial officers have a great deal of input. The company is primarily a marketing broker and financing entity. Operating personnel have less say in equipment purchases, while finance and purchasing employees assume a more important place.

4.5.2 Determining Equipment Requirements

Marketing is really the primary concern of this corporation. There is a more clear-cut perception of where the market for coal is headed than is usual with other companies. They see an increasing demand for eastern low-sulfur coal. They have many contractual commitments for this type of coal,

and are presently buying 40 percent of the coal they ship from spot markets. They have complex mixing and transshipment facilities to handle shipments and varying coal inputs. However, they are seeking to rapidly decrease their dependence on spot markets. They foresee an increasing rate of equipment purchase as they shift production to their mines and to the mines of their contractors. So, although actual coal shipments will increase, coal production levels are expected to increase at a greater rate. They will have need for a great deal of equipment in the near- and medium-term future.

4.5.3 Choosing a Vendor Company

For this company, price is the primary consideration in the choice of a vendor company. As the users of the equipment are usually the independent contractors, other considerations tend to fall away. The respondent naturally feels no need to maintain a compatible fleet, since the users of that fleet are so varied. He is thus more willing to purchase from new companies and to look at new equipment. He feels that competition in the underground mining equipment industry is far from adequate, however. The performance of the equipment and the service provided are very good, but he feels the price is much higher than warranted.

4.5.4 Financial Evaluation

The consensual decision-making process used by this company relies on informal financial evaluation techniques. Acting essentially as a broker, this company faces few risks. It knows the price of its contracted sales, it knows the cost of the coal it buys under contract from independents, and it can predict spot prices in the near future. Therefore, there is no perception of a need to proceed to more sophisticated financial tools. Good performance is almost ensured by the nature of the operation.

This diversified mining company has its coal operations headquarters geographically separated from the corporate one. However, the financial control exerted by the corporation is particularly strong. Purchasing is relegated to a minor position in the decision-making process; one indication of this is that some of the purchasing personnel were hired with a non-mining background. This is a rare occurrence in the coal industry. Decision-making is centralized in the coal operations headquarters, with financial supervision coming from the corporate staff. The respondent from this company was the Manager of Purchasing Capital Equipment.

4.6.1 Equipment Decision-Makers

This company allows the operations personnel an absolute veto of any decision on equipment. Although the coal company is larger than others interviewed, it has maintained many of the management techniques used in smaller companies. The importance of the operations department is one aspect of this. There is, however, more concern for inventory costs by this operator than is the usual case. Most operators report that they get input from their inventory managers, but ignore it to please the operations personnel. This is not the case with this operator; inventory managers are requested to suggest how costs can be lessened, and these suggestions are incorporated into the purchasing plan.

4.6.2 Determining Equipment Requirements

As a producer of high-sulfur Mid-western coal, this company is in a particularly unenviable position. Regulatory uncertainties are having a greater impact on this operator's attempts to implement strategic planning than other operators

experience. This problem is compounded by the company's experience with governmental prognostications. In 1975 the company geared up to expand production, based on their perception of government actions and government predictions. They now have a large overcapacity. Like other companies, this one claims to produce only for contract. If this is true, production should not exceed deliveries over the medium-term. However, capacity frequently exceeds deliveries. As a result, the company is trying to sell some of its equipment and it is no longer buying. It can foresee no immediate increase in demand for its coal, and is perhaps the most pessimistic of the interviewed companies.

4.6.3 Choosing a Vendor Company

As this operator has both Eastern and Western operations, it is able to compare its experience in both locations. The reputation of the local representative is more important than the reputation of the national equipment corporation from which purchases are made. In the East, this operator is able to shop for this representative even though the equipment manufacturer discourages such activity. In the West, however, the dealer territories are much larger; frequently there is only one. The respondent feels that service suffers dramatically from this lack of competition.

In general, the respondent is satisfied with the equipment he purchases. The service provided on this equipment is also at a level which he considers sufficient. Concern about inventory costs prompts purchases from the company offering the greatest savings in inventory costs, all other things being equal. This was mentioned as the best financial incentive possible. Pool arrangements between coal companies, in which agreements are made to hold major dragline parts, have not worked out well. Therefore, an agreement by the

manufacturer to hold strategic pieces at a convenient distance from the mines is a great help to the operator in keeping inventory costs down.

If there is any problem with equipment, the respondent feels it is with the quality of draglines. The quality of the product is suffering as a result of the noticeable lack of competition in this area of equipment supply. The interviewee feels tremendously constrained by this problem. There is no place for him to obtain the type of equipment he requires, other than a few American companies. Yet he is sure that he is not getting the quality he could demand were competition better than at present.

4.6.4 Financial Evaluation

As purchasing director, this respondent was not aware of the budgeting process used in the company. This is a very telling indication of the split between operations, purchasing, and finance within the organization. Obviously, unlike some other companies, input is not obtained from all internal sources. This is somewhat due to the very soft market faced by this company. No purchasing of any magnitude has been done in recent years, so careful financial evaluation has not proved necessary. Even in light of this, such a lack of communication between various departments is not uncommon in the coal industry. It is one of the greatest hindrances to equipment manufacturers when they wish to make a company-wide presentation about their equipment. Finance, operations, and purchasing are not familiar enough with each other to allow an amicable working relationship. The engendering of this relationship is one of the first tasks of any experienced salesman.

In all cases, the interviewees reported that their considerations were different when approaching the questions of purchasing for ongoing operations or purchasing to develop a new mine. The differences were in two major areas:

- o Need to Ensure Compatibility
- o Evaluation and Decision-Making Process

4.7.1 Need to Ensure Compatibility

All six interviewees agreed that they experience pressures from their maintenance and repair personnel to maintain a fleet of equipment from the same manufacturer. There are good economic reasons to do this, and such a uniform fleet is the goal of many businesses. However, the coal operators interviewed do not feel constrained to do so, except to the extent of maintaining a uniform fleet in any one mine or section. A financially superior deal from another manufacturer always outweighs uncertain future savings to be gotten by purchasing from the manufacturer of presently owned equipment.

Operator A, surface mining, does not even try to maintain a compatible fleet in any single mine. He feels that the equipment he uses, other than draglines and shovels, is almost interchangeable between manufacturers. Parts from many different suppliers can be used to repair a piece of equipment. He therefore does not think that a policy of going with the low bidder for the initial purchase is economically unsound.

The respondent for Operator B, surface and underground, holds two positions in his company; he is the

purchaser of capital equipment and he is also the manager of the spare parts inventory. He therefore is much more interested in maintaining a fleet of equipment that can be repaired from the smallest parts stockpile. Unlike the respondent for Operator A, he is evaluated on his performance in keeping inventory costs down. Even with these incentives to maintain a fleet from the same manufacturer, his position as a manager of capital purchases leads him to purchase from low bidders; he finds equipment of a certain type roughly comparable from vendor to vendor.

The mining operations of Operator C are geographically close. Many of the mines are within a few miles of each other. Nevertheless, the respondent from this company said he does not feel that inventory and maintenance savings would be enough to warrant servicing different mines from the same parts stockpile. So, while he is convinced that a uniform fleet should be maintained in any one mine, he expressed no interest in doing the same on a divisional or a local level.

The interviewees from Operator D, the energy company subsidiary, were emphatic in saying that communality is never attempted between mines. In the case of large off-the-road trucks, they do not even try to assure similar makes in a particular mine. These vehicles are produced from so many sub-contractors that parts for one are usually compatible with those for another. However, for other equipment at a mine, they do try to get certain types of equipment from the same manufacturer. There is even an attempt to get all possible equipment from the same source, as the company finds it advantageous to deal with only one supplier at a single mine.

The unique structure of Operator E, the cooperative agent, means that compatibility is never a concern to the purchasing department. The equipment will be used by

contractors and the maintenance is not a duty of this operator. Therefore, no attempt is made to ensure compatibility.

Operator F, surface mining, seems to be more interested in inventory costs than are other mining concerns. There is an attempt to service different mines from the same inventory and maintenance facility. Unlike any other of the operators, Operator F prefers to use similar equipment from mine to mine. This preference is a function of the tremendous cost of maintaining an inventory for surface mining equipment. Inventory costs are not as important to Operators A and D, the other surface producers. The tax advantages accruing to a highly capitalized utility make Operator A somewhat less concerned about high inventory costs. The cash-rich position of Operator D has a similar effect.

4.7.2 Evaluation and Decision-Making Process

In all cases, the decision to open a new mine causes a stricter evaluation of equipment needs than does simple replacement. The procedure is much more formal, and it is here that modern management techniques are most likely to emerge. It is also here that new management tools are most likely to convince operators that new equipment would be financially advantageous to their business.

The process used by Operator D is typical of that used by others when evaluating a new mine venture. Smaller companies do not perform each step to the extent Operator D is able to, but all respondents made an attempt to do so. The steps are generally as follows:

- o First, a commitment for the coal must be obtained through a long-term contract. This can range from 50 to 99 percent, depending on the company in question.
- o Then the engineering department, through a project development group, does a design plan for the mine. A general level of equipment needs will be described.
- o These plans and proposed equipment purchases are passed to the divisional manager for approval.
- o A construction engineering department or ad hoc sub-group then draws up detailed specifications.
- o These specifications are passed back to the divisional level and to the individual mine level for approval and comments.
- o After approval, a detailed financial evaluation is made of the funds needed for the mine and the expected output. The money expected from the contracted sales almost always means that the development will continue.
- o Then the purchasing process begins, as described for replacement equipment.

This detailed evaluation procedure starts with data which is more basic than that used for replacement decisions. Thus, life-of-mine financial evaluations are more likely to be

listened to at this point than at a time when production has begun.

4.8 EXPERIENCE WITH JOINT FEDERAL PROJECTS

All the interviewed companies have participated in some sort of demonstration project. Some, like Operator A (utility related surface mining), devoted much time and effort to such a project. Typically, the resources committed to these projects were in the supplying of engineering and operations personnel. The experiences and perceptions of benefits accruing from these projects and of problems arising from them center on three areas:

- o The proper role of the government
- o Questions on real commitment to the project
- o Resources the operators are willing to devote

4.8.1 The Proper Role of the Government

All operators agreed that there are some projects that are deserving of Federal research support. Equipment development is not such a project, however. Instead, large demonstration projects of new mining techniques are considered both worthy of exploration and to be the types of endeavors which could never attract private money. They are therefore considered the province of the government. Naturally, some equipment development would be necessary in the development of new techniques, but this should be secondary to the main attempt.

4.8.2 Questions on Real Commitment to the Project

This is the main concern of those who have participated in joint Federal projects. There is a genuine question in the minds of these operators that the department involved in directing the projects is truly interested in results and not just in the continuation of the project. The purpose of this study is, partially, to indicate how commercialization of equipment can be aided. It is this question that also interests the operators. In all cases, those who were participants in these demonstration projects never knew of any tangible results emerging from them. If the participants could be assured as to the good will of those they work with, they might be much more likely to enter these demonstration efforts. Such demonstrations of good will must be quite forceful in the future, considering the past experiences of these operators.

4.8.3 Resources the Operators Are Willing to Commit

Resources are categorized as being either in kind or in cash. The operators questioned were remarkably willing to commit resources in kind to demonstration projects. Personnel would be lent to the organizers of these projects and demonstration sites would be provided, even though Operator D was the only one with a strictly demonstration mine. There is little question that these promises of cooperation are genuine; such commitments have been made in the past. The results also need not be of immediate financial gain to the participating company. In fact, all the companies questioned believed that such financial gain would be unlikely. Even conceding that, they seem willing to devote the time of their highly paid engineering staff to the projects. This feeling is much more prevalent in the surface mining industry than in the underground, usually because space constraints are much more

restrictive in underground operations. However, all interviewees appear willing to devote some resources to such efforts.

Cash commitments will be less easy to garner. A piece of demonstration equipment from either governmental or private sources is difficult to place in operation, the main fear being disruption of the mining operation. The respondents do not feel that they must be insulated completely from financial loss, but they are unwilling to buy the equipment directly. The main inducement would be a short-term lease. Under such an option, most of the respondents would be more willing to try a new piece of equipment. Most, however, would still demand to see the equipment in operation in a producing mine. Nevertheless, such innovative equipment could still be placed. It is the surface operators who would be more willing to try new equipment.

5. EQUIPMENT MANUFACTURERS

Equipment manufacturers are faced with a multifaceted decision process when determining the development and marketing of their products. Decision-making involves activities ranging from an initial market evaluation to actual product development and to formulation of a specific marketing strategy. Each equipment manufacturer acts according to criteria established by both internal and external stimuli.

The following discussion describes these decision-making criteria for the three manufacturers.

5.1 MARKET EVALUATION

An underlying concern of all coal-mining equipment manufacturers is the forecasted market for coal and subsequent coal production. Related to projected demands for coal are existing and future government regulations that prove either beneficial or detrimental to coal production and usage. The three equipment manufacturers that were interviewed supported this concept of demand forecasting for coal. The actual level and usage of forecasting proved to be the major difference between them.

Manufacturer A evaluated the market by anticipating future electricity requirements which, in turn, impacted the supply of electrical power plants. From this point, a forecast for the amount of coal to be used in these power plants was made. A final analytical step involved an assessment of the equipment required to mine coal in a specific geographical area that was compatible with the power plant location.

Governmental actions were monitored in a general sense with the opinion that "government activity serves to create a constant lack of knowledge."

Manufacturer B did not conduct any original demand forecasting for the coal market. The publication, Coal Age, was cited as an information source for obtaining the anticipated size of the coal market. Observations of seam height and coal usage trends were believed to be as important as overall market demand and production. Manufacturer B did not appear to consider the impact of government activities. The company's marketing ideology centered on the assumption that an adequate market share would be received, regardless of demand and federal regulations.

Manufacturer C is equally as uncertain as Manufacturer B on the value of conducting original demand forecasting. Coal production, as related to future demands, is considered when assessing the company's market position. Additional input is provided from actual sales forecasts based on anticipated business. Again, the role of the government appeared secondary in market evaluations.

The general impression obtained from discussions with Manufacturers A, B, and C regarding these market evaluation habits was one of acquiescence. All three seem to recognize the relationship between the demand for coal and demand for their products. However, they are also of the opinion that, because of the limited number of coal-mining equipment manufacturers, each firm can maintain a market share that is adequate to sustain its operations and profitability.

Product development entails the gathering and consolidation of ideas and methodologies from many sources in the hope of creating marketable goods. This process must also establish a time frame for product development and deal with the numerous government regulations that affect final product design and marketability. The interviews conducted with the three equipment manufacturers provided insight into these decisions.

5.2.1 Sources of Product Ideas

Ideas for new products come from either within or without an organization. The final product is usually a combination of inputs from both sources.

Manufacturer A considers itself a producer of "evolutionary," rather than innovative, mining equipment. This company identifies the mine operator as the primary source of its product ideas. Products are generally developed in response to suggestions from the mining industry which are often solicited during meetings with potential customers. Occasionally, Manufacturer A will examine the product lines of its competitors. However, the existence of a specific competitor's product does not preclude the development of a similar piece of equipment by this manufacturer if a need for such equipment is perceived. Products are also developed as complements to existing manufacturers' equipment lines.

Research and development efforts of Manufacturer A are directed towards improving the operations of its equipment. Requests from customers appear to center on minimizing down-time. Manufacturer A has also recognized the need for ready erection of larger equipment (e.g., draglines), and is

currently developing a product that will meet this requirement. R & D efforts are generally treated as a fixed cost and are applied to an overhead category.

Manufacturer B is less reliant on customer input for product development. Internal sources, such as company engineers, managers and salespeople, appear to have a greater degree of influence on product design and development than does the ultimate consumer. One instance where a mine operator's product input was acted upon did not prove fruitful for Manufacturer B, apparently prejudicing the acceptance of additional external suggestions. Breaches in confidentiality are also cited as a reason for the lack of interaction between this manufacturer and potential customers. In some instances Manufacturer B has entered the market with a product which was already being offered by its competitors. Justification for this action appeared to be the perceived superior quality of its equipment.

Manufacturer B prefers that its R & D efforts be termed "innovative engineering." This firm perceives a need for increased R & D in the areas of noise reduction and roof bolting. Product development costs are generally assigned to an engineering expense account on a project basis. These expenses are then allocated to an overhead budget titled, "Program Expense."

Manufacturer C attributes most of its product ideas to "hard rock" experience in the field of mining equipment development and production. There does not appear to be a great deal of formal input from internal sources. However, a French subsidiary of the firm is credited for the development of several recent product introductions in the United States market. External input into product development is virtually nonexistent. Manufacturer C does not feel the need to be

extremely innovative and monitors its competitors' product offerings for potential development ideas. The firm is also aware of the life cycle of its products and incorporates relevant information into evaluations.

The R & D activities of Manufacturer C center around haulage equipment, where the biggest problem is believed to exist. The costing structure of Manufacturer C's R & D follows a two-step approach. Corporate divisions prepare R & D budgets which are submitted and approved by a larger, "group" section. These requests, in turn, are submitted and incorporated into the company's R & D budget. Total R & D costs are variable in the sense that they are dependent upon the company's sales to some degree. On the whole however, these expenses are treated as overhead.

5.2.2 Time Frame for Product Development

The fact exists that mining equipment manufacturers receive product design and development ideas from both internal and external sources. The consolidation of ideas requires a specific time frame for product development, testing, and introduction.

Manufacturer A, the largest of the three companies interviewed, feels that the time frame for product-related activities, from start to finish, varies according to the type of equipment and the urgency of need. No initial testing, per se, is done on the finished product prior to its introduction. At the time of introduction, Manufacturer A provides site erection and the manpower to administer several strain gauge tests. This lack of testing is due in part to the manufacturer's confidence in the quality of its products. No provisions are made for product modifications after introduction. Manufacturer A believes this practice to be too costly.

Manufacturer B suggested more definite ideas for product scheduling. Following the actual production of equipment, the firm prefers a six- to eight-month testing period. This phase basically involves an in-house test of all components. Manufacturer B recognizes the fact that market pressures frequently require the curtailment of a preferred testing period. Modifications and exchanges are provided at an additional expense to the customer.

No estimate for the development, testing, and introduction time of its products could be given by Manufacturer C. Its operations appear very flexible in terms of product scheduling. Product testing is carried out on the finished goods both at the plant and by the customer upon delivery. No provisions are made for equipment modifications after introduction. The firm's attitude was expressed as: "Set it up and let it fly!"

5.2.3 Effect of Government Regulations

The stages of product development are not conducted in a static environment. The government wields its influence over most developmental aspects.

Each manufacturer interviewed was asked to indicate which health, safety, and environmental rulings have had the most impact on the types of equipment that are produced. Manufacturer A cited electrical codes and the corresponding need for safety adjustments. Manufacturer B feels that the increased requirements for proper ventilation have precluded the use of conventional mining machinery in instances where this type of equipment would prove the most efficient. Manufacturer C agrees that ventilation rulings are serving to limit systems and types of equipment used for mining. When queried about the financial impact of the Coal Mine Health and

Safety Act, all three manufacturers indicated that this ruling had a minimal effect on their operations.

The certification requirements of mining equipment also elicited specific comments from the manufacturers. While indicating that there were no serious problems, Manufacturer A feels that the largest area of difficulty is the varying interpretations of certification inspectors. Manufacturer B feels that the time required for certification can become a problem. This firm also believes that rules are generally implemented on a "piecemeal" basis. In agreement with Manufacturer B, Manufacturer C feels that the certification process takes too much time.

5.2.4 Joint Federal Projects

On occasion, the government will request the aid of mining equipment manufacturers in the development or demonstration of specific products. Manufacturer A feels that participation in joint federal projects does not prove beneficial to the company and usually declines to take part in such activities. Alternately, Manufacturers B and C do participate when requested and have encountered no real problems with these programs. The question of patent rights seemed to be the major objection of Manufacturer A. Manufacturer B seemed mildly concerned with product rights, but was more anxious about confidentiality issues.

5.3 MARKETING STRATEGY

A necessary activity of all corporate decision-making is the formulation of a marketing strategy. A successful marketing plan should strive to achieve the following:

- o Provide consumers with an awareness of the firm's product offering
- o Inform potential customers of product attributes
- o Create a demand (in the mind of the consumer) for that firm's products

The above objectives are accomplished through the development of an appropriate mix of the following marketing functions:

- o Pricing
- o Promotion
- o Distribution

Questions related to these marketing functions were asked of the three equipment manufacturers to obtain an overview of their individual strategies.

5.3.1 Product Pricing

Theoretical pricing strategies generally revolve around the demand for a product and the related sensitivity of consumers to changes in established prices. All three equipment manufacturers feel that the demand for their products is basically inelastic and thus insensitive to price changes. With so few producers of most types of mining equipment, the consumer has a limited opportunity to engage in comparative price shopping.

Based on a market exhibiting these inelastic demand tendencies, each manufacturer has the task of determining the sales price for its products. Both manufacturer A and B use a

cost-plus pricing system. This method establishes a selling price based on the cost of materials, labor and overhead with an added profit margin. Manufacturer A indicated that its selling price also contains an escalation clause usually indexed to the price of steel to compensate for the increasing costs of raw material. Manufacturer C estimates a selling price based on prototype costs with an engineering expense allowance. This price is adjusted to reflect actual production expenses and an acceptable contribution to overhead and profits. Manufacturers A, B, and C all indicated that the final selling price of their equipment was negotiable in most instances. In no case is the return from sales of specific equipment expected to compensate the company directly for developmental or engineering costs. Such costs are considered overhead and are accounted for only by the contribution to overhead made by the sale of all equipment. Thus equipment having very high development costs has the same dollar amount charged against it as does a piece of equipment with very low development costs. In the case of Manufacturer B, even those costs of retrofitting an existing model of mining equipment are charged to overhead instead of directly to that equipment's development account.

5.3.2 Product Promotion

Mining equipment manufacturers basically enjoy a favorable position in the functional area of promotion and advertising. Customers generally seek out producers of equipment rather than waiting for the producers to come to them. Manufacturers A and B rely on trade shows and advertisements in major trade journals for the bulk of their promotion. Manufacturer C, on the other hand, believes in word-of-mouth/grapevine communication as a method of promotion.

In an industry such as mining equipment production, the sales force plays an important role in a company's marketing efforts. It is generally the responsibility of the salesperson to ascertain the needs of the customer and suggest a piece of equipment that will meet these needs. An equipment manufacturer must therefore select its sales force on the basis of technical knowledge in addition to selling experience. Manufacturers A, B, and C indicated that their salespeople also perform customer service functions after the sale. Consequently, the sales force for these manufacturers had a hand in marketing activities from the initial contact with the customer through the actual sales process and post-sales, service responsibilities.

A common promotional practice is to offer purchase incentives to potential customers. Such incentives offered by mining equipment manufacturers usually take the form of service guarantees and warranties, as opposed to specific pricing breaks. All the manufacturers that were interviewed agree that guarantees on equipment operation are not possible. They approach this problem by offering what is termed inventory incentives. With this type of arrangement, the manufacturer agrees to hold a certain inventory of spare parts. Manufacturers A, B, and C all indicated that they engage in this practice. Manufacturer C also attempts to establish spare parts depots in the proximity of its major equipment locations. Manufacturers A and B offer as an incentive the services of their engineering staffs to resolve any operational problems that might arise.

5.3.3 Product Distribution

The final component of a marketing strategy is the distribution network through which the finished product travels. The network for most producers of mining equipment,

including the three manufacturers that were interviewed, is a direct channel from producer to consumer. Middlemen are rarely employed due to the technical interface requirements for this type of product. This direct channel structure has the advantage of allowing for immediate feedback after the sale. Manufacturers A and B both feel that this is the best method of distribution to ensure ultimate customer satisfaction. Manufacturer C, on some occasions, will distribute through dealers; its sales have suffered from this.

5.3.4 General Marketing Tendencies

In summary, the decisions of mining equipment manufacturers take place in a buyers' market rather than a sellers' market. Demand for mining equipment is inelastic and insensitive to price changes. Extensive promotion and advertising are not practiced. Purchase incentives usually involve some type of service guarantee and the provision of technical support. Products tend to be distributed directly from the manufacturer to the customer, thus allowing for maximum feedback.

6. SUMMARY DESCRIPTION OF THE QUALITATIVE RESULTS

This section describes the overall summary of the qualitative results. The specific individual-level analyses upon which these results are based are contained in Appendices C and D. These Appendices contain the quantitative results of the survey for each company. These consist of a regression formula allowing prediction of behavior and a table displaying the relative importance of the survey factors to that interviewee. Also included for each respondent is a narrative description of these numerical results. The questionnaire upon which the responses are based is found in Appendix B and was administered as described in the methodology section of this report. Operator E was not included in this portion of the survey as the organization of that company was so different from that of the other concerns.

6.1 RESULTS OF QUESTIONS ON INVESTMENT

Table 6-1 reflects the relative importance placed on each financial climate factor by the specified company's representative. This Table is based on the individual descriptions in Appendix C. Technically speaking, the entries in the table represent the percentage of the variance in the rankings (of the company listed in the row) that can be accounted for by the factor listed in the column. As such, the index is a measure of the relative importance of the factor. Only variables which accounted for over 5% of the variance were included in the table.

Thus, for Operator C and Operator A, the single most important factor is unexpected costs resulting from changes in

TABLE 6-1. IMPORTANCE OF INVESTMENT CLIMATE FACTORS TO INTERVIEWED COMPANIES

COMPANY	PRODUCTION SOURCE	COMPANY TYPE	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
			Amount of Contracted Coal	Demand Certainty For Uncontracted Coal	Government Policy to Absorb Costs	Information Timeliness in Federal Rule-Making	Return Needed To Cover Capital Costs
A	Surface West	Wholly Owned by Utility Company	.099	.019	.669	-	.206
B	Surface/ Underground (50/50) East	Subsidiary of Larger Resource Extraction and Chemical Company	.892	.008	-	-	-
C	Underground Midwest	Exclusive Coal Mining Concern	.025	.062	.669	.025	.132
D	Surface West/Midwest	Subsidiary of Large American Oil Company	.275	.019	.019	-	.669
F	Surface Midwest/West	Diversified Concern	.305	.304	-	.101	.250

governmental policy. Also important to both companies, although ranking a clear second, would be a change in tax policy to produce a decrease in the return needed to cover capital costs. Amount of contracted coal and the certainty with which uncontracted coal can be sold are also significant factors, but they rank a clear third in terms of importance.

As contrasted with Operator C and Operator A, Operator F is characterized by an approximately equal weighting of Factors 1, 2 and 5. Factor 4 is also significant for this company.

Operator B is not affected by any of the factors except the amount of coal which is contracted and, to a considerably lesser extent, the certainty with which the uncontracted coal can be sold.

Operator D is unique in the sense that it is most concerned with the return needed to cover capital costs. Also significant, however, are Factors 1, 2 and 3, with Factor 1 playing a more important role than 2 or 3.

6.2 RESULTS OF QUESTIONS ON EQUIPMENT TYPES

In the first part of this section were described results designed to assess the effect of different factors in the economic climate on a mining company's likelihood of making a major investment in a new piece of equipment. Just as it was thought that factors in the economic climate would have an effect, it was also thought that factors pertaining to the equipment itself would have an effect. This section reports on the effects of six factors in terms of their impact on a major new equipment investment decision. As for environmental questions, the actual survey form is found in Appendix B.

Six factors and their levels were used to create 18 profiles; they are described in the section describing the methodology of the survey. Just as in the climate factor study, subjects were asked to rank-order the 18 profiles in terms of their likelihood of purchasing a piece of equipment characterized by the profile. Subsequent to completing this task, subjects then assessed the probability that they would purchase a piece of equipment characterized by the profile.

Specific results for each company, using both the ranking and probability data, are given in Appendix D. Table 6-2 summarizes the overall results. The rows of the table list the five companies which were surveyed. The columns of the table list the six equipment factors studied. The entries in the table reflect the percentage of the variance in the rankings (for the company listed in the row) that is accounted for by the factor listed in the column. Only variables which accounted for over 5% of the variance were included in the table.

For all companies, the safety factor and the per-ton equipment and maintenance costs seem to dominate in importance. The latter is interesting because although it is the most important for only one company, it explains over 7% of the variance for all five. The recommendation source and multi-versus single-function distinction are the least important variables. The amount of new training required is the most significant variable for Operator B and explains over 6% of the variance for three of the five companies. The per-shift production factor is interesting because, although it is important to only two companies, when it is important it is a fairly strong factor -- accounting for 66.9% of the variance in one case and 22.8% in another.

TABLE 6-2. IMPORTANCE OF EQUIPMENT CHARACTERISTICS TO INTERVIEWED COMPANIES

COMPANY	PRODUCTION SOURCE	COMPANY TYPE	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
			Per-Ton Equipment and Maintenance Costs	Recommendation Source	New Training Required	Control and Operational Position	Per-Shift Production Per Operator	Multi- Functional Equipment
A	Surface West	Wholly Owned by Utility Company	.077	-	.206	.669	-	-
B	Surface/ Underground (50/50) East	Subsidiary of Larger Resource Extraction and Chemical Company	.074	.074	.669	-	-	-
C	Underground Midwest	Exclusive Coal Mining Concern	.215	-	-	.087	.669	-
D	Surface West/Midwest	Subsidiary of Large American Oil Company	.262	-	-	.669	-	-
E	Surface Midwest/West	Diversified Concern	.257	-	.062	.228	.228	.149

6.3 LIMITATIONS

There are three potential limitations to the conclusions. First, prior to the analysis, there was no way to be certain that the subjects could relate to the ranking and probability assessment task. The R^2 figures in Appendices C and D, however, demonstrate that the derived functions were able to capture clearly the ranking (and probability assessment) data as a weighted combination of the attributes characterizing the profiles. Thus, the subjects' results indicate that they gave careful consideration to the tasks they were asked to perform.

Secondly, although we can be sure that subjects gave careful consideration to the task, we cannot be certain that they would actually respond in the way they indicated they would respond under the various scenarios. The only way this could be ascertained is if an experiment were to be conducted in which the actual changes were implemented, but this is clearly not a feasible alternative.

Finally, the results pertain only to the factors used in the study. Human processing limitations constrain the number of factors to fewer than seven. It is difficult to obtain reliable data for profiles which vary on more than five or six factors at a time, and the number of factors studied was limited accordingly. Thus, the study has no implications for other factors not included in this analysis.

Overall, however, the degree to which the derived functions are able to reproduce the original data offers a certain support for the quality of the data obtained and, in turn, for the conclusions cited above.

6.4 CORRELATIONS BETWEEN COMPANIES

Of primary interest are the relative importances placed on the various factors by the subjects. It is also interesting, however, to search for similarities and differences between the subjects in terms of their preference rankings. That is, is it possible to group the participants into various sub-groups as a function of their preference rankings? Sometimes, as a result of such groupings, certain patterns in the characteristics of group members emerge. For example, it could be that surface mining companies tend to have generally similar preference orderings among themselves but that these preference orderings are different from those exhibited by underground miners. Or perhaps mining companies that supply utility companies are characterized by preference orderings different in nature from those for operators that primarily sell on the spot market.

To investigate the presence of similarities between the preference orderings, the correlations between the rankings of the five companies were obtained. (The rankings, rather than the probabilities, were used because they vary precisely between 1 and 18 and the unit of the scale is thus held constant across the five companies.) These are listed below in Table 6-3 and 6-4. Table 6-3 is derived from the rankings for the equipment profiles and Table 6-4 is derived from the rankings for the climate profiles.

From the correlation coefficients for the equipment profiles, it is clear that Operator C and Operator F have the most similar rankings, followed by the pair Operator A and Operator E, followed in turn by the pair Operator A and Operator D. This means that Operator F and Operator C have the most similar policy with respect to the relative importance of the various factors. Although Operator A and Operator F are

TABLE 6-3. CORRELATIONS BETWEEN THE PREFERENCE RANKINGS FOR THE EQUIPMENT
PROFILES FOR THE FIVE PARTICIPATING COMPANIES

COMPANY	PRODUCTION SOURCE	COMPANY TYPE	COMPANY	COMPANY	COMPANY	COMPANY	COMPANY
			A	B	C	D	F
A	Surface West	Wholly Owned by Utility Company	-	.319	.375	.542	.604
B	Surface/ Underground (50/50) East	Subsidiary of Larger Resource Extraction and Chemical Company	.319	-	.063	.077	.189
C	Underground Midwest	Exclusive Coal Mining Concern	.375	.063	-	.036	.787
D	Surface West/Midwest	Subsidiary of Large American Oil Company	.542	.077	.036	-	.160
F	Surface Midwest/West	Diversified Concern	.604	.189	.787	.160	-

TABLE 6-4. CORRELATIONS BETWEEN THE PREFERENCE RANKINGS FOR THE INVESTMENT CLIMATE PROFILES FOR THE FIVE PARTICIPATING COMPANIES

COMPANY	PRODUCTION SOURCE	COMPANY TYPE	COMPANY	COMPANY	COMPANY	COMPANY	COMPANY
			A	B	C	D	F
A	Surface West	Wholly Owned by Utility Company	-	.298	.905	.674	.013
B	Surface/ Underground (50/50) East	Subsidiary of Larger Resource Extraction and Chemical Company	.298	-	.104	.521	.503
C	Underground Midwest	Exclusive Coal Mining Concern	.905	.104	-	.515	.051
D	Surface West/Midwest	Subsidiary of Large American Oil Company	.674	.521	.515	-	.051
F	Surface Midwest/West	Diversified Concern	.013	.503	.051	.051	-

the second most similar, what they share in common is not shared to the same extent as by Operator C. Operator B does not appear to be very similar to any of the other four companies. Finally, Operator D and Operator A seem to weight some factors similarly; but, to the extent this is true, their importance is not shared by a third company.

In considering the similarity of the climate profile rankings, the same patterns do not emerge. Based on the climate profile correlations, Operator C, Operator A, and Operator D form one relatively homogeneous subgroup, while Operator B and Operator F form a second. Thus, the companies can be partitioned into two segments in terms of the relative importance of the factors.

7. CONCLUSIONS AND AMALGAMATION OF QUANTITATIVE AND QUALITATIVE DATA

The ultimate purposes of this study are not only to describe behavior, but also to outline equipment needs, as perceived by the respondents. This section of the report brings together:

- o The quantitative results with the description of decision-making process
- o The financial evaluations as presently used and as potentially used

7.1 DESIRABLE EFFORTS IN EQUIPMENT DEVELOPMENT

In the questionnaire, both operators and manufacturers expressed their opinions as to what equipment they would both like to see developed and expect to see developed. Often the manufacturers had a much clearer idea of what the future could be expected to bring; they appeared to have the leisure for making such suppositions and to have more of an incentive to do so. The various aspects of equipment covered in the quantitative portion of the interview give an indication of how much impact each has on purchases.

7.1.1 Surface Mining Equipment

While present equipment and present mining techniques seem to be generally regarded as satisfactory, troubles have arisen as institutional friction has slowed reaction to new environmental and safety rules. A perception is growing that piecemeal changes in old techniques are not the best reaction to such a changing operational environment, from an economic

standpoint. An impression arising from comments by both the surface mining equipment manufacturer and the surface operators puts emphasis on some method of more selective stripping, whether from a new mining technique or from smaller, more maneuverable equipment, or even from some new form of equipment.

A problem in segregating strata has arisen from the need to separate overburden into two, three, or even four layers. In the case of some toxic spoil strata, the overburden is sometimes not replaced in the same order in which it was removed. The solution to this problem has been to use scrapers to remove topsoil and then to use a dragline to remove the remaining overburden. In more than one case, this technique has become not only expensive, but technically impossible. All the respondents could foresee future problems, but were continuing to use old mining techniques. The expense of running scrapers is also becoming onerous. For this problem, there were suggestions for use of smaller draglines as a corrective measure.

These equipment changes are presently being explored in the industry and probably do not need any seed money. Several of the respondents, however, felt that such changes in equipment would not be a sufficient response to the problem. The increasing complexity in earth-moving necessary to remove overburden is not the only problem. Several of the interviewees could see the inflation rate for fuel and rubber products making the present topsoil removal techniques almost prohibitively expensive. These inflationary tendencies are having an effect already on the cost of truck transportation of coal from the mine. Ideas like the cross-pit conveyor and bucket-wheel excavator, which have been rejected in the past as being too complex, might have more of a future now. Inertia works against their introduction -- they would have been

dismissed out-of-hand a few years ago -- but such is not the case now. If presented correctly to the mining industry, they should now be acceptable.

When examining the findings, the positions held by, and the antecedents of, the surface mining respondents in their respective companies are an important factor in the responses:

Company A - Vice-President of Operations (From division head)

Company D - Head of Purchasing (From Operations)

Company F - Head of Purchasing (From outside organization)

In examining the differences of the responses on equipment types (Table 6-2), one can see that the operations personnel who make purchase decisions (Companies A and D) are most concerned about the safety and security of their workers. This is not surprising, considering the fact that most surface miners work in enclosed cabs. There is obviously a desire on the part of the purchasers to maintain the pattern of having a few pieces of large equipment do most of the work, thus keeping as few men as possible in the work area. This desire, along with the economic problems, is one reason why scrapers are such a poor solution to the problem of topsoil removal. This is another indication that some sort of large-scale equipment to remove topsoil would be the development with the greatest possibilities of commercialization.

It is interesting to note also that about one-fifth of Company A's response is predicated on the new training required by the equipment. This company is a western operator and thus has trouble locating skilled workers. Highly complex equipment thus has less possibility of being introduced in the West. If such equipment is to be marketed, the effort should be concentrated in the East.

It is also worth noting that the purchasing agent from Company F, who was recruited from outside the mining industry, takes into account more (five) of the factors when making his decision. This wider viewpoint was also obvious from other aspects of the interview. Penetration of the market should be first attempted in companies that have brought in outside personnel. The chances for success will be much higher than in companies that have promoted personnel solely from operations, as the analysis of the equipment will be more broad-based.

The most interesting factors to note about the preferences for a financial climate for investment are contained in the responses of Companies A and D. Company A, the Western surface operator, is most concerned about changes in government standards; two-thirds of his response is based on that. This was reflected in his responses to narrative questions. If some form of program could be instituted to insulate this company somewhat from the financial burden of changing standards, then investment could possibly be increased.

Company D, part of an energy conglomerate, based two-thirds of its response on the return needed to cover capital costs. This is another reflection of the increased emphasis on financial evaluation that has appeared in coal companies acquired by larger concerns. Financial inducements to investment would be most effective on these companies.

7.1.2 Underground Mining Equipment

Dissatisfaction with present equipment was more widespread here than was the case with surface mining equipment. This dissatisfaction centers on one area -- the discontinuous performance of the continuous miner. The solution to this problem and, indeed, the perception of the

problem, is different from operator to operator. One considers the pullback for roof bolting to be the chief problem, while another regards shuttle car capacity as a greater cause for concern. All agreed, however, that continuous mining was a misnomer for what the equipment does. The underground equipment manufacturer put forth the thesis that no system of continuous mining could be effective until all components of the system -- i.e., simultaneous extraction and bolting and continuous face haulage -- are in place. When confronted with this idea, the operators tended to agree, no matter what their perception of the actual cause of the problem. It is this major effort to produce an entire mining system that private money will not attempt, and it is here that federal money would be most useful.

The factors most affecting underground operators are, in the case of Company B, the amount of new training required, and, in the case of Company C, the per-shift production (Table 6-2). The respondent from Company B is the manager of purchasing; the one from Company C is Vice-President of Operations. The difference between the two reflects the concern which operations personnel have for maintaining production. This is not so much a concern for the purchasing staff.

Operator B, which is expanding its surface production at the expense of that from underground, is more concerned about new training. Apparently labor skill levels are not a great concern for underground operators in the East. Even in the East, however, surface operators are having troubles with acquisition of skilled labor.

The indications of the most desired equipment type for underground use is for equipment that will greatly increase the underground worker's useful time at the face. The second most

important concept is the reduction of maintenance costs. This, coupled with the data from the rest of the questionnaire, indicates that the least complex miner-bolter would be the equipment most likely to be commercialized for underground use.

7.2 DECISION-MAKING

Operations personnel in mining companies must decide whether or not to buy equipment, while the manufacturer must decide whether or not to develop it. This has been discussed for the individual companies; several themes have emerged.

7.2.1 Mining Companies

The choice of what equipment to purchase is one depending on two factors:

- o Previous experience with vendor company and the limited number of these companies
- o Cost of the equipment

All the respondents said that up-time and reliability were their main concerns with equipment, but all of them also added that they were generally satisfied that these factors were sufficiently high at present. They therefore felt no need to examine other manufacturers or to invite production from other companies not traditionally engaged in manufacturing mining equipment. There is no real decision, therefore, regarding the company from which to purchase major equipment.

If a choice is to be made as to the mining equipment manufacturer to be used in developing new equipment, then the choice will be extremely limited. It is not that manufacturing concerns other than the major mining equipment companies could not develop mining machinery; but that, once developed, such

machinery is unlikely to be purchased. The expense of developing the intricate service networks needed before sales can be made would probably prohibit many other companies from entering the market.

Such traditionalism in the market for mining equipment does not mean, however, that all development money must be channelled through two or three surface equipment companies or through three or four underground equipment companies. Frequently mentioned by the respondents were pieces of ancillary equipment. These are as vital to proper operation as is the whole construct. It is with these individual components that non-mining expertise can be brought into the industry.

Whereas most mine operators would not be willing to accept equipment from other than traditional suppliers, there probably would be a willingness to accept a system, such as true continuous mining, developed by a less well known firm, but using equipment from traditional sources. This new system must be well demonstrated, however, and must be directed into mining applications where it best fits.

Longwall mining is a good example of both good and bad market penetration techniques. The system has been well proven in Europe and has been tried by several of the respondents and several other U.S. operators, in surprising numbers considering industry-wide resistance to change. This was partially a reaction to restrictions placed on continuous mining by new health and safety rules. Some applications were inappropriate; and the equipment was, in one case, simply abandoned. In other mines, the longwall system has performed admirably and its use is being expanded. The misapplications, however, are the ones gaining notoriety in the mining industry.

Most respondents indicated that federal money should flow into such "systems" development, rather than into research

on individual equipment. However, care must be exercised to ensure proper testing and gradual introduction into the industry.

7.3 FINANCIAL EVALUATION

Legislation leading to a financially advantageous climate for mining investment must be considered with care. Frequently, accounting and financial evaluation techniques in both the mining and equipment manufacturing industries are not organized so as to allow manipulation of the kind found effective for other industries.

7.3.1 Equipment Manufacturers

The techniques used by all the equipment manufacturers to account for development costs do not attribute these costs directly to the product involved. Instead, the costs are placed into a general overhead category. These research outlays are budgeted, but from that point on, their direct effect on profitability is lost. Tax laws which allow capitalization of such expenses would tend to make manufacturing companies more aware of the connection between development costs and the compensation coming from sales of the equipment developed. Such strict accounting should direct efforts into areas where equipment could be most easily commercialized.

None of the companies felt particularly constrained in the amount of money they devote to R & D. However, until these expenditures are more closely related to the return accruing from them, tax incentives to promote research will not be very effective. While these tax benefits will strengthen the overall health of the firm, they will not necessarily direct any increasing profits into new product development. Generally, however, the manufacturing companies are considered

strong enough to develop any equipment having possibilities of immediate commercialization.

7.3.2 Mine Operators

The financial evaluation of mining equipment, while usually performed, is rarely of interest to the operational personnel who make the buying decisions. One equipment manufacturer has developed a sophisticated program to evaluate financial impacts of new equipment and new mine development. As in the case for equipment manufacturers, more sophisticated evaluation techniques might be an inducement to make investments in more productive equipment. All coal operators attribute costs to down-time, inventory stocks and maintenance expenses. Often these costings are done intuitively, and not on the basis of any research. It is therefore extremely difficult to demonstrate to mine operators the benefits of purchasing more productive equipment. One manufacturer has developed techniques to evaluate the cost of down-time and thus to prove to coal operators the actual value of different pieces of equipment. Such techniques have been very effective if presented to the operations and finance staff at the same time.

From the experiences of this company, and from the results of the survey, have emerged a feeling that coal mining companies are at a stage where modern financial evaluation has become a necessity. The need for such techniques has been recognized within the industry; the purchase of coal companies by conglomerates has served to speed the process. This factor should serve to lessen the traditional reluctance to introduce new equipment into mines. The mining industry has had several crisis periods in which the need for new technology has been recognized, the most recent being the introduction of continuous mining. Several of the respondents felt that such a node in the history of mining has been reached again and that new equipment will have an increasingly good chance of introduction.

With the introduction of more exact financial evaluation and with the feeling that techniques must change, the time for new equipment development is here. There is presently some confusion as to direction, because of the changing market and regulatory conditions. Equipment to help mine operators meet the challenges of these changes will have a good chance of commercialization.

APPENDICES A - D

INTERNAL DECISION-MAKING

1) If you have two decisions, one in which you have:

- a) Decided to expand production; the other in which
- b) You are opening a new mine

How do your decisions differ?

2) Some people say their considerations are very different in the following areas:

- a) Need to make new equipment compatible with the old
- b) Need to make the new equipment compatible with the spare parts stockpile
- c) Need to provide retraining on the new equipment

Are these important considerations for you? If so, do they make a decision for expansion much easier to make in that they restrict your options?

3) From what sources do you elicit advice when you are in a capital purchase decision-making process?

- a) Your engineers
- b) Your consultants
- c) Your operations people
- d) The firms you deal with

Which would you rank first?

Which would you not consider at all?

4) Can you give me some idea at what point in the scale of increasing costs the purchase of a piece of equipment or of a system becomes a major capital budgeting decision and thus ceases to be just another decision for operating personnel?

5) How does the process differ between the two in:

- a) The level of management they reach and the route there?
- b) The persons consulted?

6) Of the two ways of analyzing a potential purchase which do you prefer?

- a) As a contributor to the overall health of the company;
or
- b) As a contributor to the health of a project

7) Are there any ways your capital budgeting process might surprise me in:

- a) Its departure from cut-and-dried academic cash-flow analysis?
- b) In its decentralization?
- c) In the amount of latitude given to individuals to decide on equipment types?
- d) In aspects of the cash flow analysis that I might not consider if I had experience in other business fields?
- e) In the treatment of risk and the potential market?

VENDOR COMPANY TYPE DESIRED

1) What would you say is the most important aspect of any company that you purchase major equipment from?

2) Do you most frequently return to the same source of supply or do you frequently make reevaluations of your suppliers?

3) Why would you or why would you not change? Others have suggested that they would look at these factors:

- a) Sureness of service and adherence to past delivery schedules
- b) Ease of interface with the vendor's employees
- c) Guarantees provided for operation
- d) Guarantees provided for installation
- e) Ease of access to their engineering staff
- f) Financial inducements such as:

- Cheap replacement parts
- Payment schedules
- Discounts
- Packages

4) Are these things important to you? Which would you rate the highest in your mind? Can you give examples where a breakdown in one of these factors changed your actions or, conversely, where your certainty about one of these factors made you go with a company?

5) When you are attracted to a new supplier by one means or another, what would you look for in the company's background? (We are not talking about service promises now.)

- a) Experience with your type of coal or geological conditions
- b) Length of time in business of manufacturing mining equipment
- c) Its staff
- d) Other customers it has sold to
- e) Their financial backing
- f) Their production capacity

6) Which would you most look at?

7) Would a failure to meet your standards in any one of those categories automatically exclude a company from consideration?

8) What are your feelings about customizing by your supplier?

9) Do you ever buy equipment that has not been highly customized?

10) Does this tend to be equipment below a certain dollar level of cost?

11) Are you much more likely to go with a company that:

a) Offers customization; or,

b) Offers you a lower price

12) Do you ever shop outside of the big equipment manufacturers in this country?

13) How limited do you feel with the small number of suppliers you can deal with; in other words, do you think that competition is present or is not present in current market conditions?

SURFACE MINING EQUIPMENT QUESTIONS

I. REMOVING OVERBURDEN

- 1) Are you satisfied with present equipment? Ideally, how would you like to see it changed?
- 2) How large do you feel draglines can possibly be? Do you see any limit other than a physical one?
- 3) Then you do (do not) go with the theory that bigger is always better with excavation machinery?
- 4) Cycle time is necessarily increased as the shovel or dragline gets larger. Do you have any ideas on the trade-off you are willing to make here?
- 5) Are you satisfied with the present degree of mobility of your excavation machinery?
- 6) What do you see as the deepest seam you will ever try to exploit considering all the present day factors relating to coal, its price, and its market?
- 7) Do you feel that equipment limitations or cost limitations will be the factor to determine your deepest penetration?
- 8) Everyone we have spoken to claims that removal of overburden is their greatest equipment cost (usually 50%). Do you find this to be true?
- 9) Then you probably do (do not) want to see the most progress in new equipment made in this field?
- 10) Do you have any thoughts on the use of shovels or draglines in overburden removal? Others say their decisions are based on the type of overburden and on the depth of the coal seam. How do you feel about your operations and do you think that increasingly stringent environmental rules will necessitate movement in one direction or another?

II. TRANSPORTING OVERBURDEN TO STORAGE

- 1) Are you satisfied with present equipment? Ideally, how would you like to see it changed?
- 2) How do you presently segregate the overburden? Are you satisfied with this method?

3) If you use some type of transportation, do you feel that you would like to go in the direction of larger vehicles or some type of conveyor system?

4) For what reasons do you feel this way?

- a) Effect of down time
- b) Cost of equipment
- c) Present bottlenecks in this stage of mining

III. REMOVING COAL

1) Are you satisfied with present equipment? Ideally, how would you like to see it changed?

2) Would you prefer to rip or blast to remove coal?

3) Are there any geological constraints or coal characteristics that make you feel this way?

4) Are you experiencing problems at the coal/overburden interface?

5) If so how would you like to see them solved?

- a) Smaller machinery (buckets etc.) or,
- b) More maneuverable machinery

6) Do your operations lend themselves to shovels or to loaders?

7) Are there any applications where you can see yourself using the other?

8) Are you satisfied with the electric shovels and draglines or do you see any applications for the high-pressure hydraulic systems now being developed?

9) If yes, what are the reasons?

10) I am going to list some things that others have complained about as shortcomings of present equipment:

- a) Inability to work in a high-water-table area
- b) Inability to turn in tight spaces
- c) Inability to follow a meandering seam
- d) Problems in digging below grade
- e) Problems in working on steep slopes

Are you concerned about any of these in your operations? Which would you rank as the two most serious problems?

11) Do you see any solutions to these?

IV. TRANSPORTING COAL

- 1) Are you satisfied with present equipment? Ideally, how would you like to see it changed?
- 2) Do you anticipate using anything other than large trucks in your operations?
- 3) What are the problems?
 - a) Difficulties in negotiating tight turns
 - b) Excess tire wear and tire handling
 - c) Power transmission
 - d) Down time
- 4) Do you see any ultimate size in trucks? Are you experiencing a lot of problems in the ultra-large vehicles that you haven't had with smaller ones?
- 5) Is this making you rethink the strategy of "bigger and bigger"?

V. REPLACING OVERBURDEN AND RECLAMATION

- 1) Are you satisfied with present equipment? Ideally, how would you like to see it changed?
- 2) Are you presently using methods other than those you formerly used to remove it?
- 3) Have the new reclamation rules made you needful of equipment other than that which you were using previously?
- 4) Are you facing any extreme problems segregating strata?
- 5) Would this make you rethink your replacement strategy?
- 6) Do you ever foresee a completely new system for strip mining, one that you would be interested in if it could be proven?

UNDERGROUND MINING QUESTIONS

I. EXTRACTION

1) Do you presently face problems with low seams? Is the equipment you have adequate to the task? If not, how do you see a solution to the problem?

2) Are there geological conditions you face which you consider to be unmet by present extraction equipment?

3) When you are considering whether or not to purchase a piece of face equipment, do you consider its impact on the following factors? In other words, has a failure in one of these areas ever caused you not to go with a particular piece of equipment:

- a) Dust generation
- b) Fine-coal generation
- c) Gas generation

4) In which of these areas would you most like to see progress?

5) Since _____ is a problem to you, how would you like to see it solved?

- a) By return to a more efficient conventional mining system
- b) By a change in continuous and long wall miners

6) Have you had more trouble than you have expected repositioning long-wall and/or continuous miners?

- a) If so, what is its nature?
- b) Has this made you wary of large systems?

7) If you operate long-wall systems, do you see any expansion of your use of them?

8) Do augers enter into any of your planned extraction techniques?

a) Are there any special applications you would like to see in augers?

9) Do you find that repair time and repair costs are out of line with your expectations on continuous miners? With your long wall systems?

10) Is your experience with down-time acceptable for face equipment?

11) Do you use anything like conventional mining at present?

II. FACE HAULAGE

1) Is this, in your opinion, the controlling factor in the production level on any particular section? If not, what is your constraint?

2) Do you ever foresee any immediate applications of pneumatic or hydraulic face haulage? Would you be likely to commit yourself to it?

3) Why do you think it would or would not work in your operations?

4) Are you experiencing unacceptable delays in repositioning equipment if you are using anything other than shuttle cars?

III. PRIMARY HAULAGE AND MOTIVE POWER

1) Do you think trolleys have any future?

2) Are there any situations where you would consider installation?

3) Would you like to commit yourself to diesel?

a) Do you see labor possibly changing its opinions on the subject?

b) In what applications would you use it other than haulage?

4) Are you comfortable with battery powered vehicles as far as reliability and down-time are concerned?

5) What kind of problems do you anticipate with conveyors for primary haulage?

6) Are your new sections being designed to possibly handle this?

7) What are the biggest problems you foresee in using conveyor systems?

a) Moving them

b) Down time

c) Safety

d) Maintenance

IV. ROOF CONTROL

- 1) Do you find this to be a constraint: is production often held up by the need to reinforce the roof?
- 2) Several people have mentioned that the cost is much more than it would have first seemed to be; do you agree?
- 3) Are you using anything extensively other than roof bolting? Do you see any need in your operations for a different system?
 - a) What conditions would it meet?
 - b) What do you feel you would be most likely to use?
- 4) What problems in the roof bolting process itself would you like to see solved?
 - a) Drill speed?
 - b) Dust control?
 - c) Cost of bolts?
 - d) Placement?
 - e) Bolting systems for unstable roof conditions?
- 5) Where do you anticipate seeing improvement?
 - a) Resin holding?
 - b) Cost?
 - c) Ease of placement?

V. COAL PREPARATION (Do they do it?)

- 1) Do you have problems in the recovery of fine coal? Are you interested in a system to recover it?
- 2) What problems do you foresee with such a system?
 - a) Environmental?
 - b) Cost?
 - c) Complexity?
- 3) Do you see processing as the solution of the problem of fines?
- 4) Do you anticipate demands on you to make coal cleaner at the source?
- 5) Are you gearing up for it?
- 6) If so where do you see it coming:
 - a) Physical cleaning?
 - b) Chemical?

VI. SAFETY AND HEALTH

- 1) If you are having problems with degassing would you like to see a system designed to deal with it?
- 2) What would be its broad characteristics?
- 3) Do you find your present system of dust control adequate:
 - a) At the face?
 - b) With roof bolting?
- 4) Would you prefer:
 - a) Machinery to reduce dust generation at the source?
 - b) Equipment to control already-generated dust?
- 4) How much drilling do you do? Are you having trouble with noise control here and in roof bolting?
- 5) In general, do you foresee a great need to reduce noise in mining, for whatever reasons, primarily governmental?
- 6) Do you see safety rules pushing you in one direction or another as far as type of equipment and even type of mine plan are concerned?
- 7) If so, do you think that present equipment and anticipated future equipment will be adequate to the task?

DECISION-MAKING IN EQUIPMENT MANUFACTURING

I. DECISION-MAKING PROCESS

1) Does your company receive much feedback from mining companies regarding the problem areas which they would like to see solved? Is this usually initiated by you or by them?

2) In what areas do most of these requests come?

- a) Chemical cleaning
- b) Physical cleaning
- c) Environmental problems
- d) Problems with fine coal

3) Which sources contribute the majority of your innovative ideas:

- a) Mining company
- b) Your engineers
- c) Production people
- d) Consulting engineers

4) Is the stimulus for new product development usually internal or external? In other words, do you do more pure research on products which you feel might be marketable or do you develop suggestions of the mining industry? Also do you try to market to the mining industry products which you have developed in other business lines?

5) Are there R&D projects in which the company would presently invest, but which are being passed up because of:

- a) Lack of capital
- b) Lack of market for coal
- c) Other constraints

5) Is there a perceived need for increased R&D in the coal mining sector by you and by your customers?

6) Do you look at R&D as being a fixed or a variable cost? In other words, are you willing to lessen it in times of lower profits?

7) In determining the need for a new piece of equipment in the market, you obviously go through a detailed evaluation of the market and feasibility of developing and introducing that piece of equipment. Let's talk of that evaluation step by step.

8) Evaluation of the market. What aspects of the market for processing equipment do you look at? In general, do you look at the market for coal? Do you examine environmental rules for cleaning coal? Do you look at your present position in the market? What level of demand forecasting does your firm engage in (short-term, long-term, present markets vs. new markets, etc.)?

9) Do you go to your competitors to see if they currently offer a product that will satisfy the buyer? If they do, would you be inclined to come into the market with a "Me-too" product, providing your objectives were met, or do you tend to offer only totally new products or processes?

10) In determining specific equipment characteristics, how much do you depend on your sales people?

11) How much input do you ask from potential buyers?

12) Do you ever elicit the aid of marketing consultants?

13) When and at what level is the decision to develop a prototype made if there are positive indicators about the market?

14) At what point is the eventual selling price estimated and the cash-flow analysis carried out?

15) Who in the company does your cash flow analysis? Is it at this point that the decision is made which projects to fund and which to postpone?

16) What enters into this? How do you time your expenses and inflows?

17) What kind of testing do you do of the prototype and at what stage of development is this done?

18) How much provision do you make for modifications after introduction?

19) What is the usual time period for all this development, testing, and introduction?

II. EQUIPMENT NEEDING IMPROVEMENT AND COMMERCIALIZATION

1) How would you rank the following areas as far as need for improvements:

- a) Chemical cleaning
- b) Physical cleaning
- c) Environmental problems
- d) Safety and health

2) Is there any one major bottleneck in mining which you feel slows productivity to a point where further progress in other areas becomes superfluous?

3) What progress is being made in this area?

4) What are the attributes of a company that you have found to be the most willing to experiment with new equipment?

5) What incentives have you found to be most useful in encouraging such experimentation?

6) What types of equipment have you been most successful in introducing?

7) Do you get any input from labor as far as acceptable equipment is concerned?

III. TARGET R&D FUNDS

1) Given that DOE has limited funds to spend, where do you feel these funds would be best spent?

2) Which projects do you feel have the best chance of commercial application?

IV. BUSINESS ENVIRONMENT

1) Do you feel that the national commitment to coal has been adequate?

2) What can be done about it?

3) Does FASB Statement #2 about expensing R&D expenditures have a negative effect on your efforts? How would you like to see movement in this accounting area?

4) How did the Coal Mine Health and Safety Act impact you financially?

5) When you work on joint federal projects, what problems have you had, of any nature, from interference to problems in funding and payment?

6) Do problems with patents and patent rights ever keep you from participation?

7) When you evaluate a project for its financial impact on your company, what aspects of the cash flow and risk assessment do you tend to place more emphasis on? Also how would you like to see them changed to help your company?

- a) ITC
- b) Grants
- c) Market for coal
- d) Depreciation of machine tools

8) Is financing ever a problem that has driven you away from what you feel could have been a beneficial effort?

9) How do you evaluate the return from R&D? Do you do it for specific projects or as contributors to total profitability?

10) What is the greatest obstacle to your R&D efforts?

V. MARKETING STRUCTURE

1) What is your distribution network? (What role do the salespeople play and what roles do the distributors play?)

2) Do your salespeople simply provide contact to the customer before the sale or do they serve as customer representatives and do all the follow-up work?

3) Service is often spoken of as the one thing that is absolutely demanded from any vendor. How is your service network organized?

4) What kind of incentives do you usually offer your customers in the way of price or payment breaks? Which have you found most effective?

5) What types of guarantees have you found to be demanded by your customers?

6) In general, what types of services and guarantees have you found the mining industry demanding -- services which other industrial users don't ask for?

7) What kind of advertising and promotional efforts have you found to be most effective in reaching mining executives?

8) How price sensitive have you found your customers to be?

9) What problems are you having with overseas sales?

VI. GOVERNMENTAL RELATIONS

1) What aspects of health, safety, and environmental rulings have you found to impact most on the types of equipment you are selling?

2) What aspects of equipment certification have you found to be the most burdensome?

3) How much influence do you feel that you have in Federal rule-making procedures?

(The following are reproduced from the instruction booklet given participants in the study.)

INSTRUCTIONS

As part of a project with the Department of Energy, we are interested in discovering the relative importance of different factors in terms of their effect on long-run decisions to purchase or not to purchase new mining equipment. To simplify the collection of the data for this project, we have separated potential influence variables into two types:

- o Factors related to the performance of the equipment
- o Factors related to the financial and market picture at the time a purchase decision is made.

First, let's consider factors related to the performance of the equipment. Imagine, for a moment, that you have decided to open a new section in one of your mines. This will, of course, require a great deal of new equipment and will also allow you to choose equipment and mining systems independently of your previous equipment purchases. You are therefore examining the market and comparing different models of large pieces of equipment (for example, different models of continuous miners, roof bolters, or transportation systems). Further imagine that these pieces of equipment differ from each other in terms of six basic factors which might be expected to affect your purchase decision. These factors are described in detail below. Please read and familiarize yourself with these descriptions. They will be used in the data collection task which is described in the next section.

DESCRIPTION OF FACTORS

Factor 1: Per-Ton Equipment and Maintenance Cost

The cost of running a piece of mining equipment consists of many facets. Consider, for now, only those costs related to amortization and maintenance costs per ton of coal. These include:

- o Original effective cost of the equipment (take into account discounts, trade-ins, incentives, etc.)
- o Estimated useful life of the new equipment (your best estimate, not promised life)
- o Yearly maintenance costs (both scheduled and, in your best estimate, unscheduled)
- o Work performed by the equipment expressed in terms of tons of coal (again, your estimate of actual performance not the published rating. Remember to include down-time in your estimate.)

By this, each model can be described in terms of its effects on your amortization and maintenance costs of producing one ton of coal. The models under consideration, when compared to present practice, will either:

- 1) Lower your per ton equipment and maintenance costs by 10%; or
- 2) Maintain the current level of equipment and maintenance costs; or
- 3) Increase your per-ton equipment and maintenance costs by 10%.

Factor 2: Recommendation Source

Information about mining equipment comes from a number of sources and through a multitude of channels. Exhibits, publications, and word-of-mouth provide much information. Such information can arise internally and flow to you from your subordinates. Consider for a moment, however, the primary source of a positive recommendation of the performance of a piece of equipment. This recommendation has come either from:

- 1) The engineering consultant whom you usually employ to evaluate equipment and conditions; or,
- 2) Your counterpart at another mining company which faces geological problems similar to yours and whose coal you consider similar to yours; or,
- 3) From the representative of the vendor company from which you have made previous purchases.

Factor 3: New Training Required

Pieces of equipment can differ from one another in terms of how much training they require prior to use. This retraining can be at the individual operator level where, for example, the continuous miner necessitated a whole new approach to the coal seam. Or it can be at a supervisory level where, for example, a new conveyor system can require the need for a rebalancing of the work flow. Or it can be at an even higher management level, as is the case for long-wall mining and its dictates for a new approach in mine design. In any case, when new equipment represents a revolutionary departure from previous versions, it will require training of personnel before on-the-job use. Equipment more evolutionary in design would not require this extensive retraining. The equipment models under consideration are either:

- 1) A revolutionary departure from what they replace requiring extensive training of your staff; or
- 2) An evolutionary departure which requires little additional training.

Factor 4: Control and Operation Position

One aspect of the design of a piece of equipment is the position of the operator during use. In day-to-day operation of equipment, operators are sometimes tempted to pass near dangerous areas or to expose themselves to danger in order to speed operations. Violations of posted safety rules are ignored to complete the job more quickly. On the other hand, some equipment like the newly introduced longitudinal cutting miner allow efficient operation completely from an unexposed position; some of the temptation to circumvent safety rules is obviated by judicious placement of controls and design aimed at pleasing the operator. The piece of equipment in question either:

- 1) Does not eliminate these temptations of the operator to leave a protected position; or
- 2) Eliminates those temptations of the operator to leave a protected position.

Factor 5: Per-Shift Production Per Operator

In some mines and for some tasks it has been estimated that an operator is actually productive for 50% of his shift, although this figure is probably higher in your operations. Low productivity can be a function of several things:

- o Time to and from face
- o Down-time for equipment (both planned and unplanned)
- o Time to move equipment from work place to work place
- o Cycle time for periodic movement
- o Number of men required for each piece of equipment
- o Interface problems between systems.

By alleviating some, or all, of these problems, the models under consideration will either:

- 1) Increase your operators' per-shift production by 5%;
or,
- 2) Increase your operators' per-shift production by 10%.

Factor 6: Multi-functional Equipment

Often it is possible to purchase a single machine, or system, to perform two or more tasks. We describe such inter-locking systems as multi-functional. By single-function we describe a piece of equipment which has been designed to perform only one task or a closely related series of tasks. For example, imagine you were considering the purchase of a multi-functional unit which could perform both the roof-control and coal-extracting functions or, alternatively that you were considering one unit for roof control and a separate unit for coal extraction; the equipment costs of both alternatives are identical. In general, the equipment under consideration is either:

- 1) A multi-functional unit capable of performing two major tasks; or,
- 2) A "package" of two separate units, each capable of performing one of the two major tasks.

Data Collection Task

In the attached PACKET #1 there are eighteen "profile descriptions" of potential new mining equipment. These descriptions are systematically varied in terms of the six factors we have just described. We would like you to indicate your best estimate of your relative preferences for these potential models of equipment in the following way:

Step 1: We would like to obtain your rank-order of the eighteen profiles with the most preferred ranked first, the next most preferred ranked second, and so on, with the least preferred ranked last. In accomplishing this rank order of the eighteen profiles, other participants found it useful first to separate them into three piles with the profiles in Pile #1 being the most preferred; the profiles in Pile #2 being less preferred than those in Pile #1 but more preferred than those in Pile #3; and the profiles in Pile #3 being less preferred than those in either Pile #1 or Pile #2. You are free to switch profiles from one pile to another, to write notes or comments on the profiles, or to do anything else that you think may be helpful in ordering them.

Step 2: Now recombine the piles so that the profiles are ranked from one to eighteen in order of your preference. Go through them a final time to insure yourself that they are indeed in the order you wish them to be in. You are again free to move them about as you wish.

Step 3: Because it is possible that even for the most preferred profiles you might have a very low or very high probability of purchase, we need one more piece of information for each profile. Try to estimate the probability of your purchase of the profile description model considering the situations which you face in mining. If you are absolutely certain you would buy a piece of equipment described by the profile, then record 100% for the probability-of-purchase in the space provided. If the odds are only 75%, then record a 75, etc. You are free to use any number between 0 and 100 and to use any level of exactitude you feel comfortable with. Now for each of the eighteen profiles, please record your best estimate of the probability that you would purchase a piece of equipment characterized by the profile description.

In both the rank-ordering and probability-estimation tasks, your opinions are the only variable being measured. Thus, there are no right or wrong answers; the way in which you respond is automatically correct in that it is the best indication of what we want to measure - your own preference. It is important, however,

that you believe that each of the eighteen profiles describes a piece of equipment available for purchase. Even though you might consider some of the combinations unlikely, based on your experience, please attempt to place yourself in a frame of mind from which you are able to estimate your reaction to these profiles as if they are true representatives of actual equipment.

FINANCIAL AND MARKET FACTORS

Now we would like to turn to the influence of financial and market factors on your purchase decision. To some extent, it would be likely that the anticipated future market demand would affect your current decision to purchase or not to purchase a major piece of equipment. Likewise, the current financial and regulatory picture could have some effect as well. Imagine that you are making a decision whether or not to upgrade equipment in an old section. In the following five factors we describe different possible situations which might have influence over your decisions. Please read and familiarize yourself with these descriptions carefully. They will be used in the data-collection task to be described in the next section.

DESCRIPTION OF FACTORS

Factor 1: Amount of Contracted Coal

The new equipment added to the section will certainly increase your production. You have contracted part of this additional production to a utility. The amount contracted is either:

- 1) 80% contracted; or,
- 2) 70% contracted; or,
- 3) 60% contracted.

Factor 2: Certainty Concerning Demand for Uncontracted Coal

The amount of increased production that is not covered by contract sales is studied in relation to the market for coal of that type. By projecting trends and by studying your past performance you estimate the certainty with which you will be able to sell this uncontracted coal. This degree of certainty is either:

- 1) 90% certainty; or
- 2) 80% certainty; or
- 3) 70% certainty.

You have probably studied projections of coal use from various sources in the past. For example, consider future coal consumption as projected by the U.S. government or by private forecasting services. Consider these sources and your confidence in them when you imagine yourself being 90% certain, or 80% certain, or 70% certain of some particular outcome.

Factor 3: Unexpected Changes in Government Policy

New technology, especially in mining, can have ramifications for safety and environment considerations not foreseen when first introduced. Continuous mining machines and long-wall mining with their attendant dust problems are examples. Such problems can arise even after what is considered to be extensive testing followed by federal certification. Consider then, two different approaches to this problem:

- 1) A governmental program designed to absorb adverse financial impacts should modifications or additions be mandated for equipment after its certification; or
- 2) Adverse financial impacts absorbed by mining companies.

Factor 4: Federal Rule-Making

Government policy concerning the operation of mines (safety requirements, equipment specifications, work rules, etc.) is the result of industry, labor and public reaction to agency-authored rules. Although industry will probably always play a reactive role in that process, a greater access to information in the rule-making proposal stage should help the coal industry to better plan its adjustments to changes in government policy. Thus, on this factor, we specify two levels of information input into the industry:

- 1) Industry is provided with more information at earlier stages in the rule making process; or,
- 2) Rule-making under the present system.

Factor 5: Return Needed to Cover Capital Costs

Estimated yearly return from a piece of equipment needed to cover capital cost is a function of several different factors:

- o Original cost of the equipment
- o Trade-in value of the equipment replaced
- o An investment tax credit
- o Taxable depreciation schedules
- o Cost of capital (both debt and equity)

All these factors influence your yearly break-even cash flow. Imagine that by varying any, or all, of the factors, the government and other market forces:

- 1) Decrease the yearly minimum cash flow needed to cover capital costs by 10%.
- 2) Increase the yearly minimum cash flow needed to cover capital costs by 10%.

DATA COLLECTION TASK

In the attached PACKET #2, there are eighteen "profile descriptions" of potential environments in which a purchase could be made. Use a method similar to the one used for PACKET #1 to divide the profiles into three piles based on your preference for investment environments and then to rank-order them from most to least preferred.

Because even your most preferred environment may not be hospitable enough to invite investment, we need a second piece of information. Attempt to estimate the probability of your making the purchase of new equipment in the profiled environment you ranked first. Then do the same for the remaining seventeen profiles. Again, try to evaluate the profiles as if they could actually occur, even though some of the combinations might seem unlikely to you.

APPENDIX C

INDIVIDUAL RESULTS OF RESPONSES TO
INVESTMENT ENVIRONMENT SURVEY

This appendix summarizes the results for each individual company representative. The results are based on the rankings and probability assessments for the economic environment scenarios. The equipment profile results are contained in the following Appendix.

Several abbreviations are used throughout the appendix. As a guide to understanding the results, those for Operator F are described in detail. The title for each report indicates the company name (in this case, Operator F), whether the derived function is based on the rankings or the probability assessments (Operator F-R or Operator F-P), and whether the data is for the environment scenarios or the equipment profiles.

Following the title is the function which was actually derived. If it begins with RNK = then it indicates the function was based on the rankings. If it begins with PROB = then it indicates the function was based on the probability assessments. The terms in the function are abbreviations of the factors described in the introduction. The abbreviations used to refer to these terms are:

- o GOVPOL - Unexpected changes in government policy
- o RETURN - Return needed to cover capital costs
- o CONTRC - Amount of contracted coal
- o CERT - Certainty concerning demand for
uncontracted coal
- o FEDRUL - Federal rule making

The numbers at the end of those factors characterized by three levels distinguish between the weights applicable to Level 2 versus Level 3. The Level 1 weight is embedded in the constant. Adding together the weights appropriate for any profile will give the expected value for that profile. It will be the expected value for the ranking of that profile if the function is based on the rankings. It will be the expected value of the probability associated with the profile if the function is based on the probability assessments.

Listed under the column, Variable, are the variable names corresponding to the Factors described earlier. Only variables which were statistically significant are included. Under the column, Percentage of Variance Accounted For, is listed the percentage of the variance in the rankings (or probabilities) that is accounted for by the Factor listed in the row. In the cases where both levels of the three-level factor are significant, the percentage of variance accounted for by both levels are summed and the result indicated. Finally, in the column, F-Statistic, is listed the value for the significance test, F.

The overall R^2 indicates, for the function as a whole, the percentage of the variance in the dependent variable that is accounted for by the derived function. The overall F indicates the value for the index, F, which can be used in a test for statistical significance of the function. Every subject had a clearly significant overall F value.

Function for Operator A-R (Operator A's rankings) -
Environment Profile

$$RNK = 1.833 + 9.0 (GOVPOL2) + 5.0 (RETURN2) + 4.0 (CONTRC3) \\ + 2.0 (CONTRC2) + 1.50 (CERT2) + 1.5 (CERT3)$$

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>		<u>F-Statistic</u>
GOVPOL2	.669		1018.286
RETURN2	.206		314.286
CONTRC3	.074		150.857
CONTRC2	.025	.099	37.714
CERT2	.005		21.214
CERT3	.014	.019	21.214

Overall $R^2 = .993$

Overall F = 251.952

Based on the designed profiles, the most important factor for this subject is the adverse financial impact caused by unforeseen changes in government policy. He expresses a strong preference for situations in which the government absorbs the cost for any equipment changes mandated by unforeseen changes in government policy. The second most important variable is the return needed to cover capital costs. This variable is followed in importance by the amount of coal under contract and the certainty with which there will be demand for the uncontracted coal.

Function for Operator A-P (Operator A's probability assessments) -
Environment Profile

PROB = 1.03 - .779 (GOVPOL2) - .242 (RETURN 2) - .142 (CONTRC3)
 + .096 (CERT 2) - .075 (CONTRC2)

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>		<u>F-Statistic</u>
GOVPOL2	.866		641.633
RETURN2	.083		61.725
CONTRC3	.015		15.908
CONTRC2	.006	.021	4.459
CERT2	.013		9.706

Overall R^2 = .978

Overall F = 145.798

The dominant factor for this subject is the effect of adverse financial impact caused by unforeseen changes in government policy. He would very much like to see a government program which absorbed any such costs. Ranking a distant second in importance is the return needed to cover capital costs, followed by the amount of coal which is contracted, followed, in turn, by the certainty with which uncontracted coal can be sold.

Function for Operator B-R (Operator B's rankings) -
Environment Profile

$$RNK = 3.833 + 12.00 (CONTRC3) + 6.00 (CONTRC2) - 1.00 (CERT2)$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>		<u>F-Statistic</u>
CONTRC3	.669		124.701
CONTRC2	.223	.892	31.175
CERT2	.008		1.155
Overall R^2	= .900		Overall F = 41.952

This subject has a reproducible pattern using only two variables -- amount of contracted coal and the certainty factor on the demand for the uncontracted coal. Of these two, the contracted coal factor is by far the most important; it accounts for 89.2% of the variance in the rankings. Although the certainty factor (Level 2) enters the function, it does so with an F of only 1.155 and thus doesn't represent a very important factor.

Function for Operator B-P (Operator B's probability assessments)
Environment Profile

PROB. = .833 - .833 (CONTRC3) - .383 (CONTRC2)

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
CONTRC3	.757	353.774
CONTRC2	.203 .960	74.858

Overall $R^2 = .960$ Overall F = 177.264

In terms of the probability assessments, this subject cares only about how much coal is already contracted. None of the remaining four factors matters. Furthermore, the subject exhibits a strong and observable difference in preference between 60% under contract and 70% under contract. That is, there appears to be a threshold between the 60% and 70% levels such that 60% leaves too much uncontracted coal to make a major investment (probability of 0), but 70% contracted increases the odds to 50/50 (probability of .5).

Function for Operator C-R (Operator C's rankings) -
Environment Profile

$$\text{RNK} = 2.5 + 9.0 (\text{GOVPOL2}) + 4.0 (\text{RETURN2}) + 3.167 (\text{CERT 3}) \\ + 1.75 (\text{CONTRC3}) + 1.75 (\text{FEDRUL2}) + 1.33 (\text{CERT2})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
GOVPOL2	.669	85.536
RETURN2	.132	16.896
CERT3	.052	7.942
CERT2	.011 .063	1.408
CONTRC3	.025	3.234
FEDRUL2	.025	3.234

Overall $R^2 = .914$

Overall F = 19.485

Based on the rankings, this subject most strongly favors a government policy for absorbing costs which result from equipment changes made necessary as a result of a switch in government policy. Second in importance to this subject is a change in the tax laws which would decrease the return needed to cover capital costs. The certainty with which uncontracted coal could be sold and the amount of coal contracted also affected this subject's rankings. Of equal importance with the latter is a change in the rule-making process to provide more information sooner.

Function for Operator C-P (Operator C's probabilities) -
Environment Profile

PROB = .724 - .404 (GOVPOL2) - .129 (RETURN 2) - .104 (FEDRUL 2)

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
GOVPOL2	.775	115.448
RETURN2	.079	11.791
FEDRUL2	.052	7.669

Overall R^2 = .906

Overall F = 44.969

Based on the probability assessments, this subject demonstrates effects resulting from the government policy variable, the desire to decrease the return needed to cover capital costs, and the importance of timely information from the rule-making process.

Function for Operator D-R (Operator D's rankings) -
Environment Profile

$$\text{RNK} = 1.67 + 9.0 (\text{RETURN2}) + 6.67 (\text{CONTRC3}) + 3.33 (\text{CONTRC2}) \\ + 1.5 (\text{GOVPOL2}) + 1.5 (\text{CERT2}) + 1.5 (\text{CERT3})$$

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>		<u>F-Statistic</u>
RETURN2	.669		388.8
CONTRC3	.206		160.0
CONTRC2	.069	.275	40.0
GOVPOL2	.019		10.8
CERT2	.005		8.1
CERT3	.014	.019	8.1
Overall $R^2 = .981$			Overall $F = 95.067$

The factor of most concern to this subject is the effect of the return needed to cover capital cost. More than any other variable, this factor affected the ranking of the scenarios. The most interesting aspect of this result is not that the subject prefers equipment which lowers the return needed to cover capital costs, but, rather, that this factor so strongly dominates the other factors in terms of importance -- it accounts for 66.9% of the variance. The second most important factor is the amount of contracted coal, followed by government policy concerning the absorption of adverse financial impact caused by changes in government policy, followed by the certainty with which uncontracted coal can be sold.

Function for Operator D-P (Operator D's probability assessments) -
Environment Profile

PROB = .906 - .547 (RETURN2) - .300 (CONTRC3) - .182 (CONTRC2)
- .157 (CERT2) - .107 (GOVPOL2) - .100 (CERT 3)
+ .043 (FEDRUL2)

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>		<u>F-Statistic</u>
RETURN2	.729		281.229
CONTRC3	.107		63.521
CONTRC2	.060	.167	23.293
CERT2	.028		17.323
CERT3	.018	.046	10.707
GOVPOL2	.028		7.058
FEDRUL2	.005		1.767

Overall R^2 = .974

Overall F = 53.705

Every variable entered this subject's function. Of primary importance was the return needed to cover cost of capital. This variable was followed by the amount of coal contracted, which, in turn, was followed by the certainty with which uncontracted coal could be sold. Finally, although significant, the government policy and federal rule variables accounted for only 7.8% and .5%, respectively.

Function for Operator F-R (Operator F's rankings) -
Environment Profile

$$\text{RNK} = 3.0 - 5.50 (\text{RETURN } 2) + 7.0 (\text{CERT } 3) + 7.0 (\text{CONTRC3}) \\ + 3.50 (\text{FEDRUL2}) + 4.0 (\text{CONTRC2}) + 3.50 (\text{CERT2})$$

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>		<u>F-Statistic</u>
RETURN2	.250		68.256
CERT3	.228		82.923
CERT2	.076	.304	20.731
CONTRC3	.206		82.923
CONTRC2	.099	.305	27.077
FEDRUL2	.101		27.641

$$\text{Overall } R^2 = .960$$

$$\text{Overall } F = 43.718$$

Based on the profile rankings, there appear to be three major factors affecting this subject's rankings. Almost tied in terms of importance are: (1) The return needed to cover capital costs, (2) the certainty with which uncontracted coal can be sold and (3) the amount of coal which is already contracted. The obvious directions of preference are sustained in each case. The fourth factor which is of importance in this case is the federal rule-making policy -- this subject would like more information at an earlier stage. A government policy to absorb adverse financial costs does not affect this subject's rankings.

Function for Operator F-P (Operator F's probability assessments) -
Environment Profile

PROB = .758 + .258 (RETURN2) - .292 (CERT 3) - .308 (CONTRC3)
 -.192 (FEDRUL2) - .208 (CONTRC2) - .125 (CERT2)

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>		<u>F-Statistic</u>
RETURN2	.267		89.207
CERT3	.210		85.285
CERT2	.047	.257	14.362
CONTRC3	.167		87.383
CONTRC2	.130	.297	39.894
FEDRUL2	.147		45.021

Overall R^2 = .967

Overall F = 53.902

Based on the probability assessments, this subject would be affected by four of the five factors. Roughly tied in terms of importance are: (1) The return needed to cover capital costs, (2) the certainty with which uncontracted coal can be sold and (3) the amount of coal which is already contracted. The fourth significant factor is the timing of information availability in the federal rule-making process -- this subject exhibits a clear preference for more information sooner. A government program to absorb adverse financial costs that are incurred as a result of changes in government policy would not affect the probability of making a major investment in a new piece of equipment.

APPENDIX D

INDIVIDUAL RESULTS OF RESPONSES TO
EQUIPMENT TYPE SURVEY

The following Appendix provides the detailed company-by-task reports from the equipment profile section of the questionnaire. A description of the factors is included in the methodology section at the beginning of this report. The format and the methodology are the same as for the previous Appendix; the abbreviations used are as follows:

- o CNTRLP - Control and Operational Position
- o NTR - New Training Required
- o PTEMC - Per-Ton Equipment and Maintenance Cost
- o PSPPO - Per-Shift Production Per Operator
- o RECS - Recommendation Source
- o MFEQ - Multi-functional Equipment

Function for Operator A-R (Operator A's rankings) -
Equipment Profile

$$\text{RNK} = 12.50 - 9.00 (\text{CNTRLP2}) - 5.00 (\text{NTR2}) + 3.33 (\text{PTEMC3}) \\ + 2.67 (\text{PTEMC2})$$

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>	<u>F-Statistic</u>
CNTRLP2	.669	181.813
NTR2	.206	56.115
PTEMC3	.033	18.705
PTEMC2	.044 .077	11.971

Overall $R^2 = .952$

Overall $F = 64.719$

This subject is most strongly affected by the control position variable. Second in importance is the amount of retraining required. Finally, the per-ton equipment and maintenance cost effect of the new piece of equipment is the third most important variable.

Function for Operator A-P (Operator A's probability assessments) -
Equipment Profile.

$$\text{PROB} = - .044 + .567 (\text{CNTRL P2}) + .167 (\text{NTR2}) + .067 (\text{PTMC2})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
CNTRL P2	.898	1011.500
NTR2	.078	87.500
PTMC2	.012	14.000

Overall $R^2 = .988$

Overall F = 371.000

The most important variable to this subject is whether or not the machine would tempt the miner to assume a dangerous position. The second most important variable is whether the equipment requires extensive retraining. The third most important variable is the effect on per-ton equipment and maintenance costs.

Function for Operator B-R (Operator B's rankings) -
Equipment Profile

$$\text{RNK} = 10.50 - 9.00 (\text{NTR2}) + 3.00 (\text{PTMC2}) + 3.00 (\text{RECS3})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
NTR2	.669	51.254
PTMC2	.074	5.695
RECS3	.074	5.695

$$\text{Overall } R^2 = .817$$

$$\text{Overall } F = 20.881$$

The most important variable to this subject is the degree to which retraining is required. The second most important variable is the per-ton equipment and maintenance costs effect of the equipment. The third most important variable is the recommendation source -- this subject discounts recommendations from the vendor's representative.

Function for Operator B-P (Operator B's probability assessments) -
Equipment Profile

$$\text{PROB} = .606 + .304 (\text{NTR2}) - .171 (\text{PTEMC2}) - .108 (\text{RECS3})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
NTR2	.557	39.769
PTEMC2	.176	12.545
RECS2	.071	5.045

$$\text{Overall } R^2 = .804$$

$$\text{Overall } F = 19.119$$

The pattern for this subject's probability estimates is identical to that for his rankings. The most important variable is whether or not retraining is required, the second most important is the equipment's effect on per-ton equipment and maintenance cost and the third most important variable is the recommendation source.

Function for Operator C-R (Operator C's rankings) -
Equipment Profile

$$\text{RNK} = 10.92 - 9.0 (\text{PSPPO2}) + 5.83 (\text{PTMC3}) - 3.25 (\text{CNTRL P2}) \\ + 2.167 (\text{PTMC2})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
PSPPO2	.669	302.659
PTMC3	.186	95.359
PTMC2	.030 .216	13.156
CNTRL P2	.087	39.467

Overall $R^2 = .971$

Overall $F = 109.897$

Based on the profile rankings, the most important variable to this subject is the equipment's effect on the per-shift production per operator. More than any other variable, this one affects this subject's rankings. The second most important variable is the per-ton equipment and maintenance costs. This was followed in importance by the control position for the operator.

Function for Operator C-P (Operator C's probability assessments) -
Equipment Profile.

$$\text{PROB} = .35 + .313 (\text{PSPP02}) - .275 (\text{PTEMC3}) + .125 (\text{CNTRLP2}) \\ - .10 (\text{PREMC2}) + .075 (\text{NTR2}) - .063 (\text{RECS3})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
PSPP02	.500	74.728
PTEMC3	.259	43.402
PTEMC2	.038 .297	5.739
CNTRLP2	.080	11.957
NTR2	.029	4.304
RECS3	.020	2.989

Overall $R^2 = .926$

Overall $F = 23.076$

Just as in the case with the rankings, this subject was influenced the most by the per-shift production per operator variable. The second most important factor was the potential effect of the equipment on the per-ton equipment and maintenance costs. Third in importance was the control position variable. The last two variables in the derived probability function were the amount of new training required and the recommendation source. Recommendations from the vendor company seem to be discounted.

Function for Operator D-R (Operator D's rankings) -
Equipment Profile

RNK = 15.833 - 9.0 (CNTRLP2) - 6.50 (PTEMC3) - 3.50 (PTEMC2)

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
CNTRLP2	.669	135.403
PTEMC3	.186	52.970
PTEMC2	.076 .262	15.358

Overall $R^2 = .931$

Overall F = 62.826

The most important variable to this subject is whether or not the equipment tempts the miner to assume a dangerous position. Second in importance is the variable reflecting the equipment's effect on per-ton equipment and maintenance cost.

Function for Operator D-P (Operator D's probability assessments)
Equipment Profile.

$$\text{PROB} = .116 + .317 (\text{CNTRL P2}) + .355 (\text{PTEMC3}) + .317 (\text{PTEMC2})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
CNTRL P2	.424	58.963
PTEMC3	.168	55.577
PTEMC2	.308 .476	42.837

Overall $R^2 = .899$

Overall $F = 41.708$

This subject is concerned primarily with two variables -- the tendency for the equipment to tempt the miner to assume a dangerous position and the effect of the equipment on per-ton equipment and maintenance costs.

Function for Operator F-R (Operator F's rankings) -
Equipment Profile

$$\text{RNK} = 10.42 + 6.33 (\text{PTEMC3}) - 5.25 (\text{CNTRL P2}) - 5.25 (\text{PSPP02}) \\ + 4.25 (\text{MFEQ2}) - 2.75 (\text{NTR2}) - 2.25 (\text{RECS3}) + 2.167 (\text{PTEMC2})$$

<u>Variable</u>	<u>Percentage of Variance</u> <u>Accounted For</u>	<u>F-Statistic</u>
PTEMC3	.228	71.133
PTEMC2	.029 .257	8.325
CNTRL P2	.228	65.172
PSPP02	.228	65.172
MFEQ2	.149	42.709
NTR2	.062	17.882
RECS3	.042	11.970

Overall $R^2 = .965$

Overall $F = 39.486$

This subject's rankings were most strongly influenced by the per-ton equipment and maintenance costs. Tied for the second most important variable are the control position variable and the per-shift production per operator variable. This subject also is concerned about whether the equipment is multifunctional (he prefers a single multifunctional unit) and whether new training is required (he doesn't want to do much retraining), and about the source of recommendations (he most values recommendations from a representative of the vendor company).

Function for Operator F-P (Operator F's probability assessments) -
Equipment Profile.

$$\text{PROB} = .493 + .292 (\text{CNTRL P2}) + .229 (\text{PSPP O2}) + .221 (\text{MFEQ2}) \\ - .258 (\text{PTMC3}) + .117 (\text{NTR2}) - .079 (\text{RECS3}) - .075 (\text{PTMC2})$$

<u>Variable</u>	<u>Percentage of Variance Accounted For</u>	<u>F-Statistic</u>
CNTRL P2	.306	45.078
PSPP O2	.189	27.829
MFEQ2	.175	25.842
PTMC3	.175	26.523
PTMC2	.015 .190	2.236
NTR2	.049	7.213
RECS3	.023	3.321

Overall $R^2 = .932$

Overall $F = 19.623$

Based on the probability assessments, this subject is affected most by whether the equipment forces the operator to assume a dangerous position. Having roughly the same effect are the next two variables, multi- versus single-function equipment and the effect on the per-ton equipment and maintenance costs. The last two variables to enter the function are whether there is any additional retraining required and the recommendation source -- he, too, prefers to hear recommendations from the company's vendor.