STRATEGIC SOURCING IN THE MINING INDUSTRY: A STUDY TO IDENTIFY AND DEFINE METRICS USED IN STRATEGIC SOURCING SUPPLIER SELECTION

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Abstract

Today's global competition for raw materials, equipment, services, and the legislated rules of the Sarbranes Oxley Act of 2002 (SOX) require organizations to provide policies and procedures for strategic sourcing supplier selection that both abide by SOX laws and deliver value to organizational stakeholders. This mandate, as well as the need for an increasingly strategic focus of corporate supply chain management departments, provides the basis for the current study. This study was completed using the Delphi Method and used three iterative phases of individual face-to-face interviews to identify and define the metrics that buyers, suppliers, and end-users at the participant company believed should be used for supplier selection. Participants also assigned a measure of metric consensus as to the importance of the metric and its corresponding definitional dimensions. Results of this study identified metrics and their underlying definitional dimensions that can be used in selecting suppliers for both a capital equipment shearing machine and MRO roof control products. While initial phases found that there was a great deal of differences in the metric definitional dimensions, additional iterations of the Delphi Method allowed for buyers, suppliers, and end-users to reach a consensus on the metrics, their definitions, and their importance to the evaluation. These differences indicate the importance of having a procedure in place for identifying metrics and definitions in selecting suppliers for strategic sourcing. Additionally, the process by which a consensus was reached established itself as a solid method for coming to consensus on these metrics. Future research should explore alternate ways of completing such a process, the lack of agreement between various groups, and use of the Delphi Method with different industries to identify if similar group disparities exist in other areas.

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CHAPTER 1: INTRODUCTION

Changes that are made in the area of supply chain management have an *immediate* impact on the overall costs of a company with a dollar-to-dollar cost savings to corporate revenues generation (Carter, Monczka, Ragatz, & Jennings, 2009). With recent acknowledgement of the supply chain's capabilities, there is a greater emphasis placed on the corporate supply chain to bring additional and substantial savings to corporations in new directions by using a more *strategic and long-term* approach in addition to cutting costs (Carter, Monczka, Ragatz, & Jennings, 2009).

Coupled with the fiscal savings/cost reduction demands on the corporate supply chain comes an increase in the accountability legislated by the Sarbanes Oxley Act of 2002 (SOX), which was signed into law because of the inconsistencies in financial reporting by several publicly held companies and the collapse of Enron. Section 404 of SOX requires executive management of a company to approve and attest to the effectiveness of the internal key controls established for financial reporting. One requirement of internal key controls is that a company must have a written process that can be validated and tested by external and internal auditors. SOX further requires that the policy and procedure must be repeatable, definable, and auditable for reporting. One example of an internal key control in today's newly directed, *long-term focused* supply chain is a process called strategic sourcing (Cavinato, Flynn, & Kauffman, 2006, p. 99).

Strategic sourcing is a "systematic, repeatable process to identify, qualify, specify, negotiate, and select suppliers for categories of similar spend" (Cavinato et al., 2006, p. 99). The phrase "categories of similar spend" in the strategic sourcing process refers to combining expenditures by category type and not by expenditure amount (Cavinato et al., 2006, p. 99). For

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example, a buyer would categorize a group of items that could be purchased from the same supplier and use this list to acquire bids from several available suppliers.

Strategic sourcing decisions are critical for supporting executive management in generating the greatest return on investment (ROI). To comply with SOX they must be definable, repeatable, and auditable. Strategic sourcing consists of any commodities, capital equipment, or services that are critical to success in meeting company goals and objectives. Cavinato et al. (2006) identifies bid evaluation as the supplier selection portion of strategic sourcing (p. 111). Making both informed and systematic decisions in strategic sourcing requires that the decisions be made without ambiguity among key stakeholders: the buyers, suppliers, and end-users (see Appendix A for definitions of buyer, supplier, and end-user).

The application of a clearly defined set of metrics that are shared among buyers, suppliers, and end-users could enable a supplier selection process to be definable, repeatable, and auditable. Such consistency in the supplier selection process allows the company to retain its strategic focus as well as maintain a reliable policy and procedure such that compliance with SOX is met in the supply chain management area of the business.

Problem Statement

Supplier selection is one important factor in profitability for many companies; however, in the mining industry supplier selection is often completed without a clearly defined set of metrics and/or without regard to the importance placed on each metric by buyers, suppliers, and end-users, or even occasionally without regard to metrics at all. By developing a set of agreed-upon metrics and definitions, the company can develop a strategic sourcing process that is definable, repeatable, and auditable. Consistently applied metrics can provide a structure that is SOX Section 404 compliant and assist the company in meeting goals and objectives.

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Stakeholders in mining (or other) industries set the standard for the return on investment (ROI) that the executive management groups are expected to achieve for each investment. For example, according to a chief financial officer (CFO) at one large mining company, the analysts' expectations are that no more than $3 per ton of coal extracted for sale should be invested in capital expenditures for any given year (William Lyons, personal communication, January 7, 2008). Capital expenditures for investing in the growth of the business are limited and should provide the greatest return on investment for the company stakeholders (William Lyons, personal communication, January 7, 2008).

The literature identifies three key metrics used for strategic sourcing supplier selection in order to deliver the needed value to the end-user: quality, price, and service. Price is weighted the heaviest (Dickson, 1966; Hahn, Watts, & Kim, 1990; Kannan & Tan, 2002; Watts & Hahn, 1993). Other sourcing metrics must also be discovered and defined by the buyers, suppliers, and end-users to be used in strategic sourcing supplier selection. Cavinato, Flynn, and Kauffman (2006) define quality, price, and service as three measures used in strategic sourcing; however, they clearly indicate that the three metrics can each be defined in a variety of ways. For example, Cavinato et al. (2006) defines quality using the following attributions: Deming's "nonfaulty [sic] systems," Juran's "fitness for use," Crosby's "conformance to requirements," and Feigenbaum's "a customer determination …" (p. 567). The different definitions of quality indicate ambiguities in definitions among researchers and make it likely that there may also be ambiguity in definitions among buyers, suppliers, and end-users.

Conforming Crosby's "conformance requirements" could be operationally defined in the supply chain as: *within budget* by executive management, *within terms of payment* for supply chain management, *within required lead time* for operations managers and *within specifications*

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as defined by supplier. Juran's notion of "fitness for use" could be defined as: *it works* by the supplier, *it is within the required specification as given by the end-users* to supply chain management, *it provides the greatest* ROI for the executive level, and *it provides a reliable and safe environment* for the end-users.

Ambiguity occurs among buyers, suppliers, and end-users when there is not a consistent and clearly defined set of metrics for the supplier selection bidding process. One example of ambiguity that exists among buyers, suppliers, and end-users is how each defines quality. According to the Institute of Supply Management's Purchasing Manual 2006, 80% of quality issues between suppliers and buyers are caused by poor communications as to the definition and application of quality with respect to the purchase requirements.

To eliminate this ambiguity in supplier selection for strategic sourcing, the suppliers, buyers, and end-users need to understand which metrics are used and how they are defined. The buyers, suppliers, and end-users must also agree on the importance of each of the chosen metrics. One way to assist in developing a consensus among the buyers, suppliers, and end-users is to conduct a study using the Delphi Model (Jolson & Rossow, 1971).

The Delphi Model was developed at the RAND Corporation to help forecast the look of future technologies for the U.S. Army (Jolson & Rossow, 1971). The model promotes an individualistic view of a specific topic by recruiting subject matter experts to participate in the study. Veering away from traditional focus group studies, the Delphi Model retains participant response anonymity to avoid any individual dominating or dictating the direction of the study. The Delphi Method is then used through a number of iterative phases to give the participants the opportunity to reach a consensus on the given topic (Adler & Ziglio, 1996).

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Purpose

The purpose of this study is to identify the strategic sourcing supplier selection metrics for capital equipment and commodity purchases, the weight of importance the metrics are assigned, and how each of the metrics is defined among the buyers, suppliers, and end-users in a large northeastern energy company. If an agreed-upon set of metrics and corresponding definitions is identified and defined, the company may be able to develop a strategic sourcing process that is definable, repeatable, and auditable. Consistently applied metrics provide a structure that is SOX Section 404 compliant and will assist the company in meeting its goals and objectives.

This study used the Delphi Method in three phases to identify, define, and assign a weight of importance to the strategic sourcing supplier selection metrics. Through these processes the information provided can be used to develop a policy and procedure for strategic sourcing supplier selection at the participant company as well as in other industries.

This study is not a comparison of strategic sourcing metrics of other companies or an answer to why the metrics are used in this company. It only provides a list of metrics, their corresponding definitional dimensions, and weights of importance as identified by buyers, suppliers, and end-users.

Significance of Study

This study makes a significant contribution to the field of supply chain management in the mining industry by providing the buyers, suppliers, and end-users with the opportunity to reach a consensus on the supplier selection metrics that can be used in strategic sourcing. It also fills a need identified by Kotzab et al. (2005) to do more qualitative studies in the field of supply

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chain management, and the study structure includes more than just one area (buyer, supplier, end-user) of the supply chain at the participant company. The identified need to shift procurement from tactical to a more strategic role for the purchasing function in many organizations (Carr & Smeltzer, 2000; Carter & Narasimhan, 1994; Ellram & Carr, 1994; Narasimhan & Das, 1999; Pearson & Gritzmacher, 1990; Reck & Long, 1988; Tan, 2002) requires that supply chain departments clearly understand the requirements of both the supplier and the end-user in order to deliver the most value.

In the 2008 business environment, several factors were essential to a business's success; examples of such factors include return on investment, quarter-on-quarter earnings, safety, and SOX compliance. Developing a systematic process and procedure for strategic sourcing supplier selection can provide the buyers the information required to maximize the value they deliver on commodities, capital equipment, and services. With a clear policy and procedure for supplier selection that includes a list of metrics, definitions, and weight of importance, the buyers, suppliers, and end-users identify the parameters required to participate in the mining company's procurement process.

Research Questions

The research questions in this study were established to identify the metrics currently utilized for strategic sourcing supplier selection by one company in the mining industry and should assist in explicating how buyers, suppliers, and end-users define and rate the metrics in terms of their importance:

1. What metrics are being used for decision support in strategic sourcing supplier selection?
2. Do the metrics differ among buyers, suppliers, and end-users?
3. Do the definitions of the metrics differ among buyers, suppliers, and end-users?

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4. What weight of importance do buyers, suppliers, and end-users assign to the metrics?

Scope

This study includes interviews with buyers, suppliers, and end-users from one large energy company involved in the mining industry. The company is located in the northeastern section of the United States and conducts business globally. The reason for choosing this company was its willingness to provide access to the buyers, end-users, and contacts for the suppliers to participate in this study. The expert participants chosen were buyers, suppliers, and end-users who had a minimum of 10 years of experience in their respective areas. The industry is further limited to those locations using underground coal mining operations at the participant company and only to those mines that utilize shearing machines to extract coal.

The buyers, suppliers, and end-users chosen for this study were those with expertise in the procurement and use of a capital equipment shearing machine and maintenance repair and operating (MRO) supply roof control products used at the participant company. The study was narrowed to these two areas because both items are critical components in the operations at the participant company. The shearer is used for the systematic extraction of coal at the participating company and the roof control products are used for ground control in the course of normal mining operations.

The capital equipment component for the study was the shearing machine used to extract coal from the underground mine. According to one company executive who provides shearing machines:

> A longwall shearing machine is an electrically powered, mobile machine used in underground mining. A shearing machine is used to extract a seam of bedded material (coal, trona or potash) and load it onto an armored face

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> conveyor (AFC) for transport out of the mine. The most common shearing machine designs are characterized by the use of adjustable ranging arms at each end of the chassis which can be raised or lowered to change the height of mining as required by varying seam thickness. (Mark Sanders, personal communication, January 13, 2008)

The shearing machine is the largest producing piece of capital equipment in the longwall mining operation and cuts the coal from the underground seam for extraction to the surface. The longwall method is a controversial coal extraction process that involves systematically removing a 42-inch wide section of coal in 1200-foot lengths -- a process that allows the roof to cave in behind the mining equipment, in many cases causing the surface ground to subside. The longwall process using shearing machines to extract coal is a mining technique that has been adopted globally.

The other set of supplier selection metrics chosen for this study were those associated with the purchase of roof support material. The roof support material is used to secure the roof from caving in during mining operations. The rationale for this decision is based on it being the largest single expensed commodity in the mining process and is generalizable to any longwall mine globally.

The maintenance, repair, and operations (MRO) commodity roof support material is used to secure the roof from caving in during mining operations. An analogy can be made between a bridge support pillar and a roof bolt. Both items are critical for support, one for the operation of a bridge, the other for the roof support in the operation of a longwall coal mine.

The roof support commodity item was manufactured by several different companies. One roof support company executive explained that the classical definition of ground control is that it

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is the science that studies the behavior of rock mass in transition from one state of equilibrium to another. It provides the basis for the design of proper support systems to prevent or control the collapse or failure of the roof. The easiest way to maintain the original equilibrium is to install rigid supports between the roof and floor immediately after mining so that no deformation of the roof can occur. However, because of mining methods and the movement of men and machinery, this is impractical. The problem of mine ground control is, then, to design the optimum support system in terms of safety, economy, and integration with other mining activities (Tony Calandra, personal communication, January 15, 2008).

This study identifies, for both roof control products and longwall shearer machines, those evaluative characteristics that are similar and those that differ across all stakeholders. Such characteristics have the potential to influence purchasing practices in these high-impact, large-dollar-value purchases for the participant company.

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CHAPTER 2: LITERATURE REVIEW

This chapter provides an overview of the literature that pertains to this study. The first section provides an overview of the studies directed towards strategic sourcing and how they were used to help answer the research questions and to address the problem statement as defined in Chapter 1. The second section provides an overview of the studies directed towards supplier selection and metrics as they pertain to answering the research questions and delivering the purposes of this study. The final section summarizes what is known regarding strategic sourcing, supplier selection, and metrics.

Strategic Sourcing

A critical aspect of the current study is that it addresses a process for selecting supplier metrics within the context of strategic sourcing activities. "Strategic sourcing" is a term that began to be used in the 1990s to identify a shift in the sourcing methods used by members of the supply chain, away from those that dealt with immediate price decreases based on transactional data, to methods with a more strategically directed approach that strove to address a company's long-term goals and objectives (Cavinato et al., 2006; Goffin, Szwejczewski, & New, 1997). Carter and Narasimhan (1995) identified strategic sourcing as one of the most significant trends in the 1994 North American purchasing round table discussions (cited in Narasimhan & Das, 1999, p. 2). There is a consensus in the literature on the need for purchasing to become more strategically based and to increase the transactional efficiency of its supply chain systems while concurrently decreasing the tactical side of its business (Carr & Smeltzer, 2000; Carter & Narasimhan, 1994; Ellram & Carr, 1994; Narasimhan & Das, 1999; Pearson & Gritzmacher,

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1990; Reck & Long, 1988; Tan, 2002). The term "strategic sourcing" came into use as described by Cavinato, Flynn, and Kauffman (2006):

> The purchasing function became more supply management. The buying activity became sourcing. Sourcing used to be considered as identifying and qualifying potential suppliers of a company's purchased materials and services. By adding strategic to its description, its meaning was extended to a systematic, repeatable, process to identify, qualify, specify, negotiate, and select suppliers for categories of similar spend. (p. 99)

The term "strategic" is used to describe the critical impact areas in strategic sourcing, such as capital equipment and commodity products, that have a direct and significant impact on the company goals and objectives (Cavinato et al., 2006; Goffin et al., 1997).

Researchers (Burt, Dobler, Starling, 2003; Carr & Pearson, 2002; Carr & Smeltzer, 1999, 2000; Freeman & Cavinato, 1990; Anderson & Katz, 1998) indicate that supply chain management needs to align the board of directors' mission, CEO vision, and stakeholder interest with the supplier base in executing strategic sourcing. Similarly, the research on strategic sourcing endeavors reveals that supply chain management needs to align supplier base with strategic objectives (Burt et al., 2003). Paquette (2004) discusses "sourcing as a strategic goal not just a functional department" (p. 8). A good strategic sourcing process will provide an opportunity for success to buyers, suppliers, and end-users (Paquette, 2004, p. 8). Kocabasoglu and Suresh (2006) identified three key factors in strategic sourcing: purchasing status within a given company, the use of information sharing within departments of a company, and information sharing among key suppliers. Kocabasoglu and Suresh (2006) also discussed the

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need for better communication across disciplines and the need for purchasing involvement in planning.

Strategic sourcing, after the implementation of SOX in 2002, became a process to provide a definable, repeatable, and auditable policy and procedure for the procurement of similar spend item categories of capital equipment, services, and commodities for a given company. According to Burt et al. (2003):

> Strategic sourcing is understanding the markets you're purchasing from inside and out and learning from your own organization and your suppliers' organizational processes, working as a mediator between suppliers and your organization, and capturing information and using it to improve relationships. Strategic sourcing requires two-way continuous improvement process work from each organization. Strategic sourcing is a disciplined approach that improves the value we receive from suppliers. There are four principles that set it apart from traditional or tactical purchasing: (1) define the total value of the relationship between purchaser and supplier, (2) develop solutions based on a deep understanding of the supplier's economics and business dynamics, (3) use differentiated purchasing tactics in order to optimize the economic relationship for both purchaser and suppliers, and (4) imbed the required changes in the organization so the purchaser achieves not only near-term measurable performance improvement but also the ability to continuously improve. (p. 32)

Strategic sourcing has become a process for supply managers to identify the value that the supply chain process adds to the corporate goals and objectives and to move the purchasing process away from tactical and into a more strategic arena (Cavinato et al., 2006; Goffin et al.,

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1997). Until the 1990s, the purchasing department was viewed as the keeper of contracts, terms, and conditions agreed to between a given company and its suppliers (Cavinato et al., 2006). In a progressive company, the purchasing department is recognized as the supply chain management department and is expected to deliver continual improvement. The global economy of 2008, along with China's insatiable appetite for raw materials, requires extensive strategic sourcing planning to avoid shortfalls in products, services, equipment, and raw material needed for the operations of a company (Narasimhan & Das, 1999).

The methods used in the current study encouraged the various organizational stakeholders to participate and give input into a process that covers all categories of spend for capital equipment, commodities, and services. This type of approach is widely regarded in the literature (Cavinato et al., 2006; Carr & Pearson, 2002; Carr & Smeltzer, 1999, 2000), and forward thinking firms are reported to view strategic sourcing as having the capacity to deliver sustainable competitive advantage through a value-added process that is "organized, systematic, and collaborative." "Organized" is considered as an ongoing organizational process that covers all major spend in capital equipment, commodities, or services (Cavinato et al., 2006, p. 100). "Systematic" refers to an executive mandated process that encompasses all the different spend categories and will provide, according to Cavinato et al. (2006), "…results [that] are measured using non-cost-performance [sic] metrics as well as cost savings" (p. 100). Finally, the inclusion of "collaborative" as part of the definition of the strategic sourcing process refers to the internal and external customers' input to the supply chain management group which provides the sustainable competitive advantage (Cavinato et al., 2006, p. 100; Tan, 2002; Tan, Kannan, & Handfield, 1998).

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Supply chain professionals are required to make complex effective decisions concerning sourcing and need to do so based on as many factors as possible, including understanding and working with the internal and external customers (Talluri, 2002; Goffin, Szwejczewski, & New, 1997). A strategic sourcing plan consists of a process of discovery, evaluation, selection, development, and management for establishing an effective strategic sourcing process (Burt et al., 2004). Evaluation and selection are the two areas that require decision support metrics that have an agreed-upon definition by buyers, suppliers, and end-users. Companies must also periodically evaluate the supplier base and the type of relationship established with each supplier as part of the strategic sourcing process. In doing this, the company must decide not only if the supplier meets the current strategic needs but also if the supplier can meet the future needs as well (Burt, Dobler, & Starling, 2003; Hahn, Watts, & Kim, 1990; Giunipero, 1990; Krause, Scannell, & Calantone, 2000).

Supplier Selection and Metrics

Strategic sourcing, as discussed in the previous section, is a key component to successful supply chain management, and a critical part of strategic sourcing is supplier selection (Mabert, & Venkataramanan, 1998; Spekman, 1988). Organizations tend to view the purchasing function based on the cost of a product, service, or equipment in comparison to a previous purchase (Vokurka, 1998). If a company expects to remain competitive in the global economy it will have to develop a collaborative relationship not only with internal customers, but also with external suppliers in order to utilize the supplier expertise for maintaining a competitive advantage (Das & Narasimhan, 2000; Kannan & Tan 2002; Krause, Scannell, & Calantone, 2000; Tracey & Tan, 2001; Vonderembse & Tracey 1999).

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In developing a collaborative relationship with the supplier and end-user, the buyer must develop a set policy and procedure for supplier selection that can be implemented and utilized consistently within the organization. The ability of a company to establish a collaborative relationship across the buyers, suppliers, and end-users allows the organization to take a holistic approach to its supply chain and the impact on the entire company rather than just one area of its supply chain (Lummus, Vokurka, & Alber, 1998). In establishing a collaborative relationship with suppliers, the supply chain management group needs to determine, with the support of the end-user and the input of the supplier, what metrics or measures will be used for the supplier selection process (Vonderembse & Tracey, 1999).

Metrics in its most basic form is a measurement; in business it allows the choice of a given process, item, or information to be used as a quantification of success or failure as defined by that business (Stork & Morgan, 1999). "While most agree that metrics for supply management are important, they can vary from company to company, depending on how a particular firm defines, for example, cost savings" (Duffy, 2006, p. 34). Rudzki, Smock, Katzorke, and Stewart (2006) give two anonymous quotes: "you get what you measure" and "measure what you want," confirming the importance and value of metrics and the need to clearly define what the metric is and how it will be measured (p. 140). Tankus (2006) identifies three areas to consider so that companies can realize the power of metrics: "you can't manage what you can't measure, things that are measured get done, and you can't improve what you can't measure" (p.66).

The setting of policies and procedures utilizing metrics such as accountability and reportable feedback are a critical to creating opportunities for success for the buyers, suppliers, and end-users; SOX sets a legislated criterion, and the stakeholders set the expectations for

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executive management and their staff (Connellan, 2003). Establishing a set of metrics that is consistently applied and has an agreed-upon definition among the buyers, suppliers, and end-users will help executives to support decisions being made in allocating a company's capital for current and future growth. A strategic sourcing supplier selection policy and procedure that is consistent and measurable can deliver the value a company is looking for in equipment, service, or MRO commodity purchases (Morgan & Monczka, 1996).

The literature identifies three key metrics used for strategic sourcing supplier selection in order to deliver the needed value to the end-user: quality, price, and service. Price is weighted the heaviest for the most part (Hahn, Watts, & Kim, 1990; Kannan & Tan, 2002; Watts & Hahn, 1993). Other metrics identified in previous research include: innovation (Tracey & Tan, 2001; Trent & Monczka, 1998), technology (Narasimhan & Das, 1999), product design (Carter & Narasimhan, 1994), supplier relationship (Gunasekaran, Patel, & Tirtiroglu, 2001), process improvement, continuous improvement, and response time (Kannan & Tan, 2002).

Cavinato et al. (2006) and others discuss the application of accepted metric quality and its application for strategic sourcing by buyers, suppliers, and end-users (Kannan & Tan, 2002; Wisner & Tan, 2000; Shin, Collier, & Wilson, 2000). Cavinato et al. (2006) identify five different definitions for quality by individuals, including the American Society for Quality, confirming a clear need for agreed-upon definitions between buyer, supplier, and end-user (p. 567). Deming defined quality as "nonfaulty systems" (p. 567). Joran defined quality as "fitness for use" (p. 567). Philip Crosby defined quality as "conformance to requirements" (p. 567). Feigenbaum defined quality as a customer's experience based on stated requirements (p. 567). The American Society for Quality defines quality as a "product or service free from deficiencies" (p. 567). In the strategic sourcing process, buyers, suppliers, and end-users must agree upon the

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definition of quality to ensure the greatest ROI for the investment their company makes on equipment, services, and MRO commodity products. On-time deliveries carry a 99% rating of very important to somewhat important with over 1,000 respondents in *Modern Materials Handling* magazine (Specter, 2004, p. 29). The high rate of response and importance comes from what would be considered an end-user in the mining industry.

Price in its simplest form is the cost of a given product, service, or capital equipment to the buyer (Cavinato et al., 2006; Hahn, Watts, & Kim, 1990). However, when evaluating this metric, other elements that must be considered and defined to the supplier are terms of payment, freight cost, surcharges, and for a piece of equipment, the cost of operation. Price can be measured old price versus new price, actual versus budget, first bid versus last bid, or lowest acceptable price versus final price paid (Cavinato et al., 2006).

Service can be more difficult to define than the expected quality of a given commodity, service, or capital equipment (Cavinato et al., 2006; Wisner & Tan, 2000). Service can be defined as quality of problem solving, technical training given, responsiveness, invoice problem resolutions, or quality of request for quotations.

Innovation is a key to lasting success in business in 2007 (Hamel, 2002; Tracey & Tan, 2001; Trent & Monczka, 1998). Value networks such as suppliers, buyers, and end-users and their relationships are part of the business model of success in the global market place (Hamel, 2002). Innovation and partnering with suppliers and end-users is defined as having a common understanding of how each outlines innovation as a metric for strategic sourcing. Hamel (2002) discusses the lack of companies using innovation as a metric. Innovation can provide sustainable growth where cost cutting and business efficiencies will only go so far before the opportunities will dry up (Hamel, 2002). Hamel's notion is to create opportunities through innovation and

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lead the business community rather than following with things like right-sizing and cost-cutting measures.

Identifying who will be responsible managing the metrics and how the measurements will be used in strategic sourcing supplier selection will eliminate ambiguity on the part of buyers, suppliers, and end-users (Brown, 2000). The strategic sourcing process should include the metrics to be used, what weight of importance is assigned to each metric, how the metrics will be defined, and who will be responsible for evaluating the metrics.

Evaluation

The literature reviewed relates to strategic sourcing, supplier selection, and metrics on a macro level more than on item specific definitional dimensions on how a metric is specifically defined for a given organization. The individual decisions made are vital in the mining industry because extensive equipment purchases or commodity purchases can have significant impact on the financial and operational goals and objectives. Through this literature review, I did not find studies conducted specifically for the mining industry. However, the application of the metrics and the use of supplier measures for supplier selection are generalizable to the mining industry. Whether in manufacturing or in mining, the need is the same as identified in the literature, to drive value to the organization and provide a means for improved performance.

Both books and journal articles identify the need for collaboration of buyers, suppliers, and end-users in strategic sourcing decisions; however, the literature leaves room for further studies into defining and weighting metrics for strategic sourcing supplier selection on the micro level. The micro level should bring the metric to the organizational items such as a shearing machine or roof control products that are to be measured for supplier selection. The literature also provides different metrics to choose from and information on how to manage the metrics to

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identify support for supplier selection policy and procedure at a given organization; this is also applicable in the mining industry. However, the literature is limited in developing a process to incorporate the involvement of the buyers, suppliers, and end-users holistically into developing an agreed-upon list of definitional dimensions for the strategic sourcing metrics. The metrics can be used in the bidding and sourcing process for capital equipment, commodity, and service requirements. The literature reviewed to date also is limited in identifying the metric definitions for commodity, capital equipment, and service purchases, which may vary and leaves room for further studies in this area.

Chapter Summary

The typical purchasing function since the 1990's has been evolving into a strategic process, moving away from the tactical process and developing one that is on the strategic level. Dickson (1966) previously identified a need for a vendor (supplier) selection process in companies; however, the view was more on price, whereas the literature through 2008 identifies a need to drive value in this process. Strategic sourcing is allowing companies to derive more value not only from the supply chain function, but also from the suppliers through a collaborative process involving buyers, suppliers, and end-users.

In 2008, collaboration is giving current organizations the ability to compete in an ever increasing global economy. The collaboration should include all segments of the supply chain: buyer, supplier (manufacturer or distributor), and end-user. By developing this process, organizations are able to deliver better value to their end customer. In these processes buyers, suppliers, and end-users are able to develop a supplier selection process that is based on a set of metrics that are defined to fit the need of the organization and the commodity, service, or capital equipment needs of the organization.

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Metrics in their most basic form are used to measure the success and/ or failure of a specific item, such as capital equipment, service, or MRO commodity products needed for the operation of a business. Although research has identified quality, price, and service as normal metrics with price being weighted the heaviest, there are new metrics being brought to the forefront in the collaborative process (Hahn, Watts, & Kim, 1990; Kannan & Tan, 2002; Watts & Hahn, 1993). Research has identified such metrics as innovation, supplier relationships, continuous improvement process, and response times as items that are important to organizations today.

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CHAPTER 3: METHODOLOGY

This chapter describes the research design used to answer the research questions: what metrics are being used for decision support in strategic sourcing supplier selection; do the metrics differ among buyers, suppliers, and end-users; do the definitions of the metrics differ among buyers, suppliers, and end-users; and what weight of importance do buyers, suppliers, and end-users assign to the metrics? Additionally, a fourth research question determines whether or not a consensus has been reached among buyers, suppliers, and end-users on strategic sourcing supplier selection metrics. The first section is an overview of the project, describing the purpose of the study. This section explains why qualitative research is appropriate for this study and specifically why a case study was utilized. The second section describes in detail the Delphi Method, participants, data collection, and data analysis. The final section provides a summary of the chapter.

Overview

This field project used the Delphi Method as a data gathering technique in a case study approach to identify and compare the supplier selection metrics used by buyers, suppliers, and end-users in the purchase of major capital equipment and commodity products for a large northeastern mining company. In a set of initial in-depth interviews and two follow-ups, techniques from the Delphi Method were incorporated to assess the degree to which consensus among all three groups could be attained. The buyer and end-user participants were drawn from a single company. The analysis of supplier selection metrics was narrowed to one maintenance repair and operation (MRO) commodity group and one piece of capital equipment used in the extraction of coal. The Delphi Method was used in an effort to assist the group in reaching a

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consensus for the supplier selection metrics used in the mining industry. The buyer and end-user participants were selected from the participating company. This study was narrowed to one maintenance repair and operating supply (MRO) commodity group and one piece of capital equipment used in the extraction of coal.

Creswell (2003) identifies qualitative studies as ones that take place in natural settings, and are emergent and not preconceived. A case study gives the researcher the opportunity for in-depth exploration of a process, at a given company, over a given time period and through a specific data collection method (Creswell, 2003; Stake, 1995; Yin, 2003; Yin, Bateman, & Moore, 1985). Yin (2003) asserts that case studies are appropriate in emerging fields of study.

Kotzab et al. (2005) noted a deficiency in the publishing of rigorous qualitative research studies in the field of supply chain management. The adoption of a qualitative approach was appropriate for this study because it helps answer the questions: what are the metrics for supplier selection; are they different among buyers, suppliers, and end-users; and what weight of importance is assigned to the metrics for supplier selection? This case study fulfills another objective of the study, to gather data from more than one area of the supply chain (Kotzab et al., 2005). That was accomplished in this study by gathering data from the buyers, suppliers, and end-users of a specific piece of capital equipment and roof control products. The data was collected using in-depth interviews to obtain rich, thick descriptions from the buyers, suppliers, and end-users. The Delphi Method was used to facilitate group consensus on the supplier selection metrics.

The Delphi Method was originally developed at the Rand Corporation in 1944 by Helmer, Dalkey, and Gordon to obtain group consensus based on the assumption "n heads are better than one" (Jolson & Rossow, 1971, p. 444). The Delphi Method as described by Linstone

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and Turoff (1975) requires participants to complete a paper and pencil survey or a computer based survey as described by Adler and Ziglio (1996).

The purpose of the Delphi Method is to begin with a broad approach, and through phases, identify the priorities and attempt to reach a consensus among the participants (Saizarbitoria, Landin, & Casadesus, 2006). Dunn (1994) noted the participant's point of view should be broad (cited in Rayens & Hahn, 2000).

The Delphi Method is typically viewed as a two-part process. The first part is the discovery process, and the second part is the evaluation process (Linstone & Turoff, 1975; Adler & Ziglio, 1996). In the discovery process, the first series of questions is used to identify the issue and receive feedback and comments from the participants. The responses are used to develop the second series of questions to refine the information, to address any disagreements, and to develop the questions for the third series if needed. There is no limit to the number of series of questions that can be used for the Delphi technique (Linstone & Turoff, 1975; Adler & Ziglio, 1996).

This method allows using individuals from the groups of buyers, suppliers, and end-users to obtain the opinions and thoughts across the supply chain among the buyers, suppliers, and end- users. Linstone and Turoff (1975) and Adler and Ziglio (1996) provide the following list as potential reasons for using the Delphi Method:

The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis:

- The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise

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- More individuals are needed than can effectively interact in a face-to-face exchange
- Time and cost make frequent group meetings infeasible
- The efficiency of face to face meeting can be increased by a supplemental group's communication process
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured
- The heterogeneity for the participants must be preserved to assure validity of the results i.e. avoidance of domination by quantity or by strength of personality (`bandwagon effect') (qtd. in Adler & Ziglio, p.4)

The Delphi Method is a relevant approach, as it will allow the buyers, suppliers, and end-users an opportunity, through collaboration, to reach a consensus of metrics and metric definitions for the strategic sourcing supplier selection. It also gives this researcher an opportunity to assess the basis on which consensus was reached or the factors that obstructed consensus. Strategic sourcing supplier selection metrics in the mining industry is a topic that does not lend itself to an exact technique but can be better served with the Delphi Method through the subjective thoughts and opinions of the participants of the study. "Delphi is a consensus technique that provides for the systematic solicitation and collation of judgments on a particular topic" (Preble, 1984, p. 1). "When viewed as communication processes, there are few areas of the human endeavor which are not candidates for application of Delphi" (Lindstone & Turoff, 1975, p. 4). In this study, with a panel of experts from the supply chain consisting of buyers, suppliers, and end-users, the Delphi Method was used in an attempt to establish group consensus for supplier selection metrics.

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Individual experts in this study reported to some of the other experts in the study, and therefore response confidentiality was critical to obtaining participants' honest opinions on the metrics and their weight of importance. The Delphi Method permitted each participant to freely express opinions and thoughts on strategic sourcing supplier selection metrics used in the mining industry without confidentiality concerns. The Delphi Method used in this study is very similar to the method identified by Linstone and Turoff (1975), but there were some differences. The first difference is that this study used face-to-face individual interviews rather than paper and pencil or computer based surveys to collect the data. The second difference was the use of a Metric Consensus Measure to identify the level of consensus reached among the buyers, suppliers, and end-users. Each participant participated in assigning a weight of importance and defining each of the metrics. The multiple phase method using a Metric Consensus Measure for consensus validation is similar to that used by Harvey (2006), and Meier, Humphreys, and Williams (1998). In a multiple phase method, participants answer questions extensively, the results of which are summarized by the researcher, then shared and validated within each group (buyers, suppliers, and end-users). Then, following validation, the results are summarized across groups, and once again shared and validated. The number of iterations is up to the researcher, and in the case of the current study, three iterations were used.

Participants

According to Gordon (1994), participant selection is critical to the success of the Delphi Method:

> The key to a successful Delphi study lies in the selection of participants. Since the results of a Delphi depend on the knowledge and cooperation of the panelists, persons who are likely to contribute valuable ideas are essential to include. In a

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statistically based study, such as a public opinion poll, participants are assumed to be representative of a larger population; in Delphi, non representative, knowledgeable persons are needed. (p. 9)

In this current study, 21 participants – seven buyers, seven suppliers, and seven end-users – volunteered to participate. Each participant had the ability to end participation at any time during the study. Each participant was contacted either face-to-face or over the phone to solicit participation in this study.

The participants used in this study were chosen because they were willing to participate through an iterative face-to-face interview process and because they had extensive experience and could be considered subject matter experts as buyers, suppliers, or end-users; however, they were not necessarily representative of all buyers, suppliers, and end-users of the capital equipment or commodity. The approach of recruiting participants with extensive experience does contradict one of the requirements set forth by Linstone and Turoff (1975) and Adler and Ziglio (1996). However, each participant could be expected to provide valuable opinions, thoughts, and insights as a result of levels of experience, and it was determined that recruiting such a group of experienced participants should actually enhance the current study as a result of a need for a strong domain knowledge of the research areas due to the complexity of each item's purpose in mining operations.

Buyer Participants

There were seven buyer participants in this study. The buyers chosen for participation in this study were recruited because they have ten or more years of experience in one or more of the following areas: MRO and capital equipment procurement, budget process, strategic sourcing, supplier selection, finance, sales, or accounting. The buyer participants have 210 years of

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combined experience in the above areas. Table 3.1 provides characteristics about the seven buyer participants, including their years of experience, the title of their current position, and indicators of their educational and professional credentials. Only one buyer lacks an undergraduate degree. All other buyers hold B.S. degrees in mining engineering or accounting. Two of the buyers hold masters degrees.

Table 3.1 Buyer Characteristics

Participant	**Experience**	**Current Position**	**Education**
Buyer 1	31-years	Senior Vice President	B.S. Mining Engineering
Buyer 2	32-years	Executive Vice President	B.S. Accounting, Masters, CPA, CMA
Buyer 3	33-years	Supply Chain Engineer	B.S. Civil Engineer
Buyer 4	37-years	General Manager	Some College
Buyer 5	28-years	Executive Vice President	B.S. Engineering
Buyer 6	18-years	Vice President	B.S. Accounting
Buyer 7	31-years	Senior Vice President	B.S. Mining Engineering, MBA

Supplier Participants

There were seven supplier participants in this study. The supplier participants for this study were chosen because they have 10 or more years of experience in one or more of the following areas: sales, product design, manufacturing, distribution, inventory management, or sales management. There are four different supply organizations used in this study; three are manufacturers and one is an industrial distributor. Two of the manufacturers produce capital equipment and the third produces MRO commodity products. The industrial distributor provides a broad mix of equipment and products used in the mining and industrial sectors of business.

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Suppliers were chosen based on involvement in the manufacturing of a shearing machine, roof control products, or based on involvement as a distributor for these products. The supplier participants have 185 years of combined experience in the areas of sales, manufacturing, distribution, inventory management, or sales management. Table 3.2 provides characteristics about the seven supplier participants, including their years of experience, the title of their current position, and indicators of their educational and professional credentials. All of the suppliers hold B.S. degrees in engineering, finance, accounting or business administration. One of the suppliers holds a Ph.D. in mining engineering.

Table 3.2 Supplier Characteristics

Participant	**Experience**	**Current Position**	**Education**
Supplier 1	32-years	President	Ph.D. Mining Engineering
Supplier 2	26-years	Vice President	B.S. Mining Engineering
Supplier 3	35-years	President	B.S. Business Administration
Supplier 4	34-years	Vice President	B.S. Business Administration
Supplier 5	15-years	Strategic Alliance Manager	B.S. Finance
Supplier 6	33-years	Vice President	B.S. Civil Engineering
Supplier 7	10-years	Vice President	B.S. Accounting

End-User Participants

There were seven end-user participants in this study. End-user participants for this study were recruited because they have 10 or more years experience in one or more of the following areas: maintenance, mining, engineering, equipment operation, longwall mining, or mine management. The end-user participants have 181 years of combined experience in the above

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listed areas. Table 3.3 provides characteristics of the seven end-user participants, including their years of experience, the title of their current position, and indicators of their educational and professional credentials. All of the end-users have bachelor's degrees in engineering. One of the end-users has a doctorate in mining engineering and another has a Masters of Business Administration degree. All of the end-users hold key positions in the mining operations of the participant company.

Table 3.3 End-user Characteristics

Participant	**Experience**	**Current Position**	**Education**
End-user 1	30-years	Mine Superintendent	B.S. Mining Engineering
End-user 2	26-years	Senior Geomechanical Engineer	Ph.D. Mining Engineering
End-user 3	24-years	Manager Maintenance	B.S. Mechanical Engineering
End-user 4	16-years	Assistant Manager Maintenance	B.S. Electrical Engineering
End-user 5	34-years	Vice President	B.S. Mining Engineering, MBA
End-user 6	20-years	Business Process Manager	B.S. Engineering
End-user 7	31-years	General Manager	B.S. Electrical Engineering

Data Collection

The Delphi Method (as it is applied to the current research) is an iterative process through which interviews are conducted and from which the results generated during those interviews are used for the creation of questions for each of the subsequent iterations. Denzin and Lincoln (2005) divide the interview process into the following group categories: type, setting purpose, role of interviewer, question format, and purpose. The group categories provided by Denzin and

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Lincoln allow the researcher to use a systematic and rigorous process in the interviews that are conducted for the research project. This is an important facet of qualitative research. The current study fits into Denzin and Lincoln's (2005) concept of interview groupings shown in Table 3.4.

Table 3.4 Denzin and Lincoln Interview Grouping

Type	**Setting Purpose**	**Role of Interviewer**	**Question Format**	**Purpose**
Focus Group	Formal, preset	Directive	Structured	Exploratory, pretest
Brainstorming	Formal or informal	Nondirective	Unstructured	Exploratory
Nominal/Delphi exploratory	Formal	Directive	Structured	Exploratory, pretest
Field, natural	Informal, spontaneous	Moderately nondirective	Very unstructured	Exploratory, Phenomenological
Field, format	Preset In field	Somewhat directive	Semistructured	Phenomenological

The current study was of a field format "type," as described in table 3.4, which used the Delphi technique individually with each participant in an effort to reach a group consensus across buyers, suppliers, and end-users for strategic sourcing supplier selection metrics at the participant company. The interviews were set in advance and took place in the field with the "setting purpose" to make participants comfortable in their environment and elicit honest and comprehensive responses. The "interviewer's role" was a "directive" approach and focused on obtaining the opinions and thoughts of the participants with respect to the question topics. Also following Lincoln and Denzin (2005), the "question format" was "semistructured" in that the initial questions were set, but then the probing or clarification questions that followed were based on the participants' responses and were geared towards obtaining the metrics used for supplier

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selection in the mining industry and how they are defined. Creswell (2003) also identifies the one-on-one interview as a valid method when participant observation is not possible. Stake (1995) purports that the interview process is a source of pride for the researcher which helps the researcher get to the various views of participants on the subject matter.

All participants were asked if they were willing to participate in this study. If participants were willing, all interviews were taped after each participant signed a statement of agreement. The study consisted of an iterative process, utilizing the Delphi Method to conduct three separate individual face-to-face interviews. In the first phase, participants identified a list of metrics, defined them, and assigned a rank order of importance to each metric. The assigned rank of importance in the first phase of the interview process identified where participants started when they began the interview. In the second phase, after reviewing with the participants the first interview results and a Metric Consensus Measure, the interviewer attempted to assist participants to reach a consensus on the metrics, weight of importance, and how each metric was defined. The purpose of the third phase was to determine if, in fact, the participants were in agreement.

By conducting in-depth face-to-face individual interviews with the buyers, suppliers, and end-users, I gained an understanding of how each of these groups defined and assigned weight of importance to the strategic sourcing metrics used in supplier selection. My understanding was guided by the following interview processes. Phase one was used to identify the list of metrics, definitional dimensions, and the weight of importance each participant felt was important in supplier selection. Phase two was to introduce the identified list of metrics, definitional dimensions, and weight of importance to all participants and to revise the list based on participant input. Phase three was to identify the final list of metrics, definitional dimensions,

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and weight of importance based on the majority input of buyers, suppliers, and end-users. Details of these phases follow.

First Phase Interview

The first phase was an in-depth interview using a specific list of questions at each participant's interview location. The purpose of the first phase interview was to identify the buyers, suppliers, and end-users list of metrics and definitional dimensions the participants believe should be used for strategic sourcing supplier selection. The information collected in the first phase interview was for answering research questions RQ1, RQ2, and RQ3. The questions asked of participants were designed by the researcher to address the differences in supplier selection metrics and definitional dimensions noted from the analysis of the first phase to attempt an opportunity for a consensus among the buyers, suppliers, and end-users. The questions that were asked during the first phase interviews were:

1. Is there a value to having a consistent set of metrics for strategic sourcing supplier selection? Why or Why not?
2. Do you believe the metrics used for supplier selection in strategic sourcing are the same among buyers (executive management and supply chain management), suppliers (design engineer, salesman, and executive management), and end-users (operations, machine operators, mechanics, and managers)? Why or why not?
3. What metrics would you use for capital equipment (shearing machine) purchases for strategic sourcing supplier selection?
    a. Why?
    b. How would you define each of these metrics?
    c. What weight of importance would you assign each with the total equaling 100?

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d. What definitional dimensions would you assign to each of these metrics?

4. What metrics would you use for commodity purchasing (roof control products) in strategic sourcing supplier selection?

    a. Why?

    b. How would you define each of these metrics?

    c. What weight of importance would you assign each with the total equaling 100?

    d. What definitional dimensions would you assign to each of these metrics?

The first phase of in-depth interviews took place in the fall of 2007, either in the office of the participant, or in some cases my office, based on the participant's preference. The average length of time of each interview was approximately 40 minutes, resulting in a transcript on average of seven single spaced typed pages.

The data collected from the first phase was analyzed and reviewed to create a list of supplier selection metrics, definitions, and weight of importance. From the data analysis of the first phase, a follow-up set of questions was developed to be utilized during the second phase interviews.

Second Phase Interview

The second phase of interviews was completed in an in-depth interview style at each participant's work site during the final two weeks of December 2007. Information collected in the second phase interviews was used to refine the list of metrics and the definitional dimensions. Each participant was asked a set of questions that was formulated from the analyzed results of the first phase. The questions were designed to provide the participants the opportunity to review the complete set of metrics and definitional dimensions identified in the phase one interview and suggest changes. The questions asked during the second phase interviews:

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1. Do you agree with the metric nomenclatures as provided by participants as listed?
    a. Why or why not?
2. Would you change any metric nomenclature?
    a. Why or why not?
    b. If so what change would you recommend?
3. Would you add or eliminate any of the metrics provided?
    a. Why or why not?
    b. If so what change would you recommend?
4. Do you agree with the definitional dimensions as provided by the participants for each metric?
    a. Why or why not?
5. Would you eliminate or add any definitional dimensions as provided by the participants for each metric?
    a. Why or why not?
6. Do you believe this set of metrics and definitional dimensions provided by the participants is appropriate for supplier selection?
    a. Why or why not?
7. Do the definitional dimensions define the metrics as provided by the participants?
8. What weight of importance would you assign to each metric with the total equaling 100%?
9. What Metric Consensus Measure score would you assign to each metric inclusive of its definitional dimensions as to its appropriateness for supplier selection?

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The second phase interviews were analyzed and the metric and definitional dimension were entered into an Excel spreadsheet. These results were then compared to the output from the phase one interviews. In order to determine if the phase two recommended changes should be made, a metric change criterion and a definitional dimension change criterion were established. The metric change criterion required that the *majority* of participants had to request a change in a metric in order for the change to be made. The definitional dimension change criterion allowed for all new definitional dimensions to be added, and that any change, alteration, or deletion of an existing definitional dimension would have to be agreed to by at least one buyer, one supplier, and one end-user. One buyer, one supplier, and one end-user were identified as those who would be contacted for change resolutions for definitional dimensions based on the aforementioned criterion.

These results were analyzed, and a six-point Metric Consensus Measure was developed for the third phase interviews to decide if a metric and definitional consensus had been reached for supplier selection metrics, definitions, and weight of importance among buyers, suppliers, and end-users.

Third Phase Interview

The third phase interviews were completed during the month of January 2008. The information collected was used to answer RQ4 and to determine if a consensus had been reached on supplier selection metrics and their underlying definitional dimensions among the buyers, suppliers, and end-users. To obtain a score for the Metric Consensus Measure for the final list of supplier selection metrics, definitional dimensions, and weight of importance, participants answered questions on a six-point Likert scale. For the purpose of this study, a consensus was reached with a Metric Consensus Measure score of 3.01 or greater. A list of questions was

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designed from the second phase interview analysis. The questions asked in the third phase interviews:

1. What weight of importance would you assign to each metric inclusive of the definitional dimension list?
2. What Metric Consensus Measure score would you assign to each metric inclusive of the definitional dimensions as to its appropriateness for supplier selection?
3. Do you see a value in doing this process across the buyers, suppliers, and end-users?

The data was analyzed to determine if, through the Delphi Method, a consensus on the metrics and definitional dimensions has been reached among the buyers, suppliers, and end-users.

Data Analysis

Data analysis was completed using a six-step process identified in Creswell (2003). Creswell (2003) identified these six steps for data analysis:

1. Organize the information collected through interviews and make it ready for transcription, scanning, or typing up from field notes.
2. Read the information and learn what the participants are saying and decide if the data is credible. Is the information able to support your study?
3. Codify the data and begin the analysis as it relates to your study.
4. Develop the themes to describe participants, places, or events as it relates to your study.
5. Do the qualitative narrative as it applies to your study through discussion.
6. Do the final interpretation of the data as it relates to your study and develop the discussion of your findings. Discuss the implications of your findings.

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The data analysis completed for this study through the three phases of interviews conducted following the Delphi Method was well aligned with Creswell's (2003) six-step process.

Phase one data analysis began by completing 21 individual face-to-face interviews during October 2007. The interviews were then transcribed into 156 single spaced pages of information by an individual hired to transcribe the interviews. The information was read and studied to get an understanding of the participants' responses and then codified into a list of metrics and definitional dimensions. The list of metrics and definitional dimensions were entered onto an Excel spreadsheet for further analysis and were further broken down by participant groups. The metrics and definitional dimensions had to be divided into two categories – shearing machine and MRO commodity roof control products – because the two areas differ greatly, and it was expected that their metrics (or at the very least, the definitional dimensions) may vary greatly. The average number of metrics was calculated for each participant group. The dimensions were reviewed for commonality, and the initial list of metrics for a shearing machine (six) and MRO commodity roof control products (five) was developed. The initial list of dimensions was used to create a list of questions and a list of metrics and their corresponding definitional dimensions for the phase two interviews.

Phase two data analysis began by completing 21 individual face-to-face interviews beginning in December 2007, and completed in January 2008, using the questions and worksheet created from the phase one analysis. The interviews were then transcribed into 171 single spaced pages of information by an individual hired to transcribe the interviews. The information was then codified into a list of changes, deletions, or alterations to the metrics and definitional dimensions and categorized into the shearing machine and MRO commodity roof control

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products. Then the information was entered into an Excel spreadsheet for analysis, where a breakdown by the participating groups was completed, and the results were assessed against the change criteria for both metrics and definitional dimensions, mentioned earlier in this chapter. Once change criteria were evaluated, those that met the criteria for the final metric and definitional dimension list along with questions for the phase three interviews were added to the final document.

Phase three data analysis began by completing 21 individual face-to-face interviews during January and February 2008, using the questions and worksheet created during the phase two analyses. The Metric Consensus Measure scores and the weight of importance were entered into an Excel spreadsheet for analysis. The data was sorted by participant group and the average Metric Consensus Measure score and weight of importance were calculated for review to determine if there was a consensus among the buyers, suppliers, and end-users as to their appropriateness for supplier selection. This study used descriptive statistics, and a standard deviation was calculated for the Metric Consensus Measure and weight of importance for each group to determine the degree of agreement among the buyers, suppliers, and end-users. The information from the final analysis was used to report the findings in Chapter 4 and to develop themes for discussion in Chapter 5.

The data validation was completed by what Creswell (2003) identified as member validation. Member validation, although not called that explicitly in Delphi, is part of the iterative process of the Delphi Method. In the case of the current research's application of the Delphi Method and member validation processes, results of participants are validated, explained, and refined at the end of each phase using the criterion for consensus at both the metric and

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definitional dimension levels (described earlier in this discussion). Similarly, the participant groups each reviewed the final list of metrics and definitional dimensions and assigned a metric consensus measure on a scale from 1 to 6.

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CHAPTER 4: RESULTS

The first section of this chapter summarizes the process of data collection and analysis. The second section provides the results of the analyses for each product across the three phases of data collection, by research question. Although data collection for each of the research questions occurred iteratively throughout the different phases, this manner of presentation of the results by research question was performed to highlight the final results of the Delphi Method under the research question for which each was relevant. The third section summarizes the chapter.

Data Collection and Analysis Summary

The results from the phase one interviews identified the metrics and definitional dimensions for the two products (shearing machine, roof control). The interviews were transcribed, a list of metrics and definitional dimensions were identified, and the information was entered into a spreadsheet for the purpose of identifying common definitional dimensions. To refine the list of metrics for supplier selection and provide a basis for comparison across the three groups for both products at the participant company, the individual responses were identified by membership in the participants' group (buyer, supplier, or end-user).

Phase two interviews were used to present the metrics and definitional dimensions as defined in phase one to each of the buyers, suppliers, and end-users and allow their input for recommended changes to these initial metrics and their associated definitional dimensions. In order to determine when a change proposed by a participant was to be included in the study, change criteria were established. The metric change criterion required that the majority of participants request a change in a specific metric in order for the change to be made to that

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metric. The definitional dimensions change criterion required that any proposed changes, whether additions, alterations, or deletions of the phase one established definitional dimension, must be agreed to by at least one buyer, one supplier, and one end-user. Phase two interviews were also used to identify the buyers', suppliers', and end-users' weight of importance for each of the identified metrics and a Metric Consensus Measure (MCM) score on a scale of 1-6 (strongly disagree to strongly agree) as to the appropriateness of the metrics and their corresponding definitional dimensions for supplier selection.

Phase three interviews were used to identify both the final weight of importance and Metric Consensus Measure score assigned by the participants. The summarized Metric Consensus Measure results were used to determine if a consensus had been reached among buyers, suppliers, and end-users. Consensus was defined as a metric or definitional dimension with a Metric Consensus Measure score greater than that of the scale mid-point (i.e. for the scale (1-6) used in this study, an MCM > 3.0 showed consensus). The use of a scale's mid-point as the cut-off for determining that consensus has been reached among participants in a study has been established in the work of Harvey (2006) where he used it to determine agreement among experts about the importance of information technology factors used to comply with Sarbanes Oxley Section 404.

Data analysis was completed using the following process: the transcribed interviews were read, and the metric list and definitional dimensions identified by each buyer, supplier, and end-user were entered into a spreadsheet. The metric and definitional dimension list was decomposed into the two product areas of the study, the shearing machine and roof control. The metric and definitional dimension list was categorized into the participant groups (buyers, suppliers, and end-users). Tables were constructed using the metric and definitional dimension

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lists from the phase one, two, and three interviews to report the results. The Metric Consensus Measure scores and the weight of importance percentages were used to construct tables to determine if a consensus among buyers, suppliers, and end-users had been established.

Research Question One RQ1

What metrics are being used for decision support in strategic sourcing supplier selection?

Phase One

The first phase of interviews during October, 2007, resulted in the identification of seven unique metrics and their associated definitional dimensions used at the participant company in strategic sourcing supplier selection for shearing machines and roof control products. The set of metrics and definitional dimensions was generated from transcribed interviews of buyers, suppliers, and end-users of the two products. There were a total of 21 interviews with seven participants from each of the participating groups. The questions asked during the phase one interviews are available in Chapter 3.

Table 4.1 depicts the list of the six unique metrics that were identified by the buyers, suppliers, and end-users as essential for strategic sourcing supplier selection related to the procurement of shearing machines and roof control products.

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Table 4.1 Phase One Metric List

Shearing Machine	**Roof Control**
Availability	Availability
Economics	Economics
Quality/Performance	Quality/Performance
Supplier Measures	Supplier Measures
Safety and Service	
	Service and Design
Technology	

Participants also identified the initial definitional dimensions that they believed comprised each of these seven metrics. Following are the metrics with their initial definitional dimensions for the Shearing Machine.

1. **Availability** (Product Lead Time, Inventory Availability, Inventory Location, MRO Main Component Availability);
2. **Economics** (Acquisition Cost, Total Cost of Ownership, Cost/Ton, Exchange Rate, Freight Cost, Lease or Buy, Lowest Present Value, Maintenance Cost, Major Component Cost, Payment Terms, Performance Guarantee, Performance Payment, Rebuild Cost, Standard Wear Item Cost, Update Cost (Technology or Components), Inventory Costs, Repair Component Cost);
3. **Quality/Performance** (Average Tons Mined, Component Access on Machine, Component Ease of Change, Cutting Speed, Downtime, Ease of Repair for Mechanics, Ease of Use, Fit for Use, Haulage Tract Power- Draw Bar Pull, Headgate Turnaround Time, Horsepower Ranging Arm and Haulage, Machine Cutting Capacity, Machine Uptime, Quality Assurance Program, Warranty Length of Time, Warranty Parameter,

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Warranty Tonnage, Tailgate Turnaround Time, Unplanned Outages, Warranty Claim Process);

4. **Safety and Service** (Body Positioning, Communication b/t End-user and Engineer, Continuous Improvement Process, Design Review, Dust Rating, Engineering Resources, Installation Help, Joint Performance Ownership, Lubricant Management, Online, Off Site, On Site Service, Personnel Qualification, Problem Analysis, Response Time, Safety Characteristics, Training Availability, Service Availability);
5. **Supplier Measures** (Alliance Investment, Alliance Length, Consortium Spend, Financial Strength, Fleet Size, Historical Performance, Manufacturing Capacity, Procure-to-Pay Process, Product Lifecycle Management, Product Support, Research and Development Spend, Rebuild Warranty, Supplier Background, System Integration, Transaction Cost, Product Enhancements);
6. **Technology** (Diagnostic Capability, Electronic Information Availability, Information Flow, Onboard Health Monitoring, Online Vibration Analysis, System Integration, Continuous Technology Improvement Process, Electronic Parts Book, Maintenance Indicators, Online Lube Information, Safety Support, Technical Capability)

Similarly, the metrics and their definitional dimensions for the Roof Control products were identified. Participant responses for Roof Control products produced the following definitional dimensions:

1. **Availability** (Inventory Availability, Lead Time, Distribution Support, Vendor Managed Inventory);
2. **Economics** (Total Cost of Ownership, Standardization, Payment Terms, Material Handling Surface-to-Face, Market Price, Lowest Present Value, Inventory Cost, Install

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Technique, Acquisition Cost, Cost per Foot, Cost per Ton, Coupling Time, Discount Structure, Freight Cost, Index Control, Install Speed);

3. **Quality/Performance** (Tensile Strength Range, Steel Grade Standard, Roof Support Reliability, Raw Material Consistency, Random Inspection, Quality Control Spend, Quality Assurance Program, Product Specification Consistency, Product Lawsuits, Product Consistency, Mill Certifications, Application Standard, Baseline Specification, Consumption Rate, Cost Effective, Ease of Installation, Ease of Use, Elongation Range, Failure Rate, ISO Certified, Material Availability, Material Chemistry);
4. **Service and Design** (Roof Safety History, Safety Characteristics, Safety Support, Safety Training, Safety Value (supplier safety record), Service Availability, Service of Supply, Test Equipment – Off/On Site, Testing, Training Availability, Product Design & Support, Product Mix, Product Requirement Support, Quality of Response, Response Time, Personnel Availability, Product Approval (MSHA) Support, Anchor System, Design Optimization, Education and Training, Emergency Response Time, Engineering Resources, Geo-Technical Engineering, Grout Control Engineering Analysis, Grout Control Engineering Availability, Grout Control Engineering Studies, Grout Control System Availability, Installation Training, Inventory Analysis, Length of Service/Durability, Load Safety Factor, On-Time Delivery, On/Off-Site Support);
5. **Supplier Measures** (Manufacturing Capacity, Number of Full Time Employees, Number of Plants, Performance Reputation, Plant Efficiency, Plant Equipment, Plant Location, Procure-to-Pay Process, Research and Development Spend, Resolution to Failure, Supplier Support for Developing Cost Structure, System Integration, Liability Insurance Level, Alliance Partnership, Bonded, Collaborative Effort for Product Requirements,

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Consortium Spend, Continuous Improvement Process, Customer Satisfaction, Ergonomic Support, Financial Strength, Growth, Historical Performance, How Many Patents, Inventory Support).

Phase Two

Phase two was conducted during the month of December, 2007, when each of the participants reviewed the list of metrics shown in Table 4.1 and their corresponding definitional dimensions at individual face-to-face interviews and were provided with an opportunity to suggest changes to the metrics and/or their corresponding definitional dimensions.

This second of three phases provided the first opportunity for buyers, suppliers, and end-users to review the entire list of metrics and definitional dimensions as identified by each participant. Metric change criterion for addition, deletion, and alteration was set as:

- any addition, deletion, or alteration would be made only at the request of the majority of participants.

Metric modifications were to be made based on the phase two interviews' participant-recommended changes. No follow-up interviews with individual participants were completed.

The change criteria for the definitional dimensions for additions, deletions, and alterations were set as:

- definitional additions to dimensions were made at any participant's request without consultation of other participants;
- deletions of dimensions were made only with agreement of one buyer, one supplier, and one end-user;

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- alterations were made only with agreement of one buyer, one supplier, and one end-user.

Agreement with one buyer, one supplier, and one end-user was established through follow-up conversations, as described in Chapter 3, after data analysis was completed. The questions asked during phase two can be found in Chapter 3.

Overarching Metric Changes

The only suggested change to the shearing machine or roof control metrics was to split the metric quality/performance and make quality and performance separate metrics. Since this change was suggested by only two participants, this metric was not changed.

Underlying Definitional Dimension Changes

Multiple additions, deletions and alterations occurred during this phase to the definitional dimensions that comprise the metrics for the shearing machine. The following is a list of shearing machine metric and the definitional dimension changes as agreed to by the participants.

Availability

- inventory availability was changed to inventory availability, visibility, and location;
- MRO main component availability was changed to MRO critical component availability, inventory location was deleted, and distribution support was added.

Economics

- total cost of ownership was deleted,;
- transaction cost was added;
- major component cost and maintenance cost were combined to major component and maintenance cost;

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- inventory cost was changed to inventory carrying cost.

Quality/Performance

- average tons mined, unplanned outages, warranty claim process, ease of use, downtime, horsepower ranging arm and haulage, fit for use, warranty parameter, and machine cutting capacity were deleted;
- machine uptime was changed to machine availability;
- warranty length of time and warranty tonnage were combined as warranty time and tonnage; rebuild warranty, plant application compatibility, and machine life expectancy were added.

Safety and Service

- body positioning, design review, and problem analysis were deleted;
- dust rating was changed to dust controls;
- safety characteristics was changed to safety support;
- response time was changed to service response time;
- training availability was changed to safety, maintenance, and operation training availability;
- machine ergonomics and training module availability were added.

Supplier Measures

- alliance investment, and product support were deleted;
- historical performance was changed to historical performance on offered design; procure-to-pay was changed to procure-to-pay with system integration;
- alliance length was changed to supplier alliance length and relationship;
- market share, warranty claim process were added.

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Technology

- safety support, and electronic information availability were deleted;
- diagnostic capability was changed to diagnostic and forensic ability;
- onboard health monitoring was changed to onboard and remote monitoring;
- automation reliability was added.

Phase Three

Phase three took place in January and February, 2008, and was for the purpose of the buyers, suppliers, and end-users reviewing the final list of metrics and definitional dimensions as given and adjusted through the first two phases. The questions asked for phase three can be found in Chapter 3.

Table 4.2 and 4.3 depict the buyer, supplier, and end-user results from the interview questions for the shearing machine and the roof control products. The table provides the Metric Consensus Measure score (MCM) broken down by the metric and participating group.

Table 4.2 Mean Scores, Shearer

Shearing Machine Metric List

Metric	**Buyer MCM**	**End-User MCM**	**Supplier MCM**
Availability Average	5.57	5.43	5.20
Economics Average	5.57	5.71	5.80
Quality/Performance Average	5.71	6.00	5.80
Safety and Service Average	5.71	5.71	5.80
Supplier Measures Average	5.29	5.14	5.20
Technology Average	5.14	5.71	5.80

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Table 4.3 Mean Scores, Roof Control

Roof Control Metric List

Metric	**Buyer MCM**	**End-User MCM**	**Supplier MCM**
Availability Average	5.57	5.43	5.75
Economics Average	5.57	5.71	5.75
Quality/Performance Average	5.57	6.00	6.00
Service and Design Average	5.57	5.43	5.50
Supplier Measures Average	5.14	5.00	5.25

As indicated by the descriptive statistics in tables 4.2 shearing machine metric list and 4.3 roof control metric list, there was a high average rate of agreement based on the Metric Consensus Measure scoring averaging over 5 on a scale of 1-6 (strongly disagree to strongly agree) between buyer, supplier, and end-user as to the appropriateness of the list of metrics and definitional dimensions for strategic sourcing supplier selection.

Research Question Two RQ2

Do the metrics differ among buyers, suppliers, and end-users?

Phase One

This question was used to determine if there are any differences in the buyer, supplier, and end-user metrics employed in strategic sourcing supplier selection at the participating organization. This question was answered during phase one of the interview process; because the ultimate goal of the Delphi Method was to reach a consensus, the determination had to be made using the initial values. The information provided by the buyers, suppliers, and end-users was integrated to build tables of the metrics and definitional dimensions for each group and were

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separated by shearing machine and roof control products. This provided a graphical representation of each group's metrics and definitional dimensions for strategic sourcing supplier selection.

Table 4.4 provides the list of the buyer shearing machine metrics as provided by the analysis of the phase one interviews. The table provides a list of 6 metrics (availability, economics, quality/performance, safety and service, supplier measures, and technology) for the buyers, suppliers, and end-users. No differences existed in the overarching metrics used for strategic sourcing supplier selection.

Table 4.4 Strategic Sourcing Metrics for a Shearing Machine

Buyer	**Supplier**	**End-user**
Availability	Availability	Availability
Economics	Economics	Economics
Quality/Performance	Quality/Performance	Quality/Performance
Safety and Service	Safety and Service	Safety and Service
Supplier Measures	Supplier Measures	Supplier Measures
Technology	Technology	Technology

These results show that the overarching metrics identified by participants across categories were identical for the shearing machine with respect to the selection of strategic sourcing suppliers of this product. Table 4.5 shows similar results for the roof control products.

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Table 4.5 Strategic Sourcing Metrics for Roof Control Products

Buyer	Supplier	End-user
Availability	Availability	Availability
Economics	Economics	Economics
Quality/Performance	Quality/Performance	Quality/Performance
Service and Design	Service and Design	Service and Design
Supplier Measures	Supplier Measures	Supplier Measures

For the roof control products, no differences were found in the overarching metrics reported by buyers, suppliers, and end-users as being important in strategic sourcing supplier selection. Research question two was answered using the output of the phase one interviews with 21 participant buyers, suppliers, and end-users -- a total of seven participants from each group. Phases two and three provided each participant with the opportunity to review and recommend changes, deletions, or alterations to the metrics or the underlying definitional dimensions based on the criteria discussed in this chapter to effectively come to a consensus on the metrics and their underlying dimensions. Consequently, phases two and three interviews were not required or used to answer this research question.

Research Question Three RQ3

Do the definitions of the metrics differ among buyers, suppliers, and end-users?

Research question three asks if there was a difference in metric definitions as reported by buyers, suppliers, and end-users. Phase one interview results were used to construct tables to determine whether or not there were differences in the underlying definitional dimensions used

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by the buyers, suppliers, and end-users. Tables were constructed to determine the amount of difference among the following groupings: buyers, suppliers, and end-users; buyers and suppliers; buyers and end-users; and end-users and suppliers. The data identified in the following tables identify the results from the 21 individual face-to-face interviews in phase one.

Table 4.6 provides numeric descriptors to provide the percentage of the definitional dimensions shared among buyers, suppliers, and end-users. Table 4.6 includes the total number of definitional dimensions, matched definitional dimensions, and the percentage of definitional dimensions matched for each of the metrics.

Table 4.6 Shearing Machine Common Definitional Dimensions Among Buyers/Suppliers/End-Users

	Availability	**Economics**	**Quality/ Performance**	**Safety and Service**	**Supplier Measures**	**Technology**
Definitional Dimension Count B/S/E	4	17	20	16	16	12
Definitional Dimension Match B/S/E	2	2	4	3	2	0
Match Percentage	50%	12%	20%	19%	13%	0%

The information contained in Table 4.6 indicates a low percentage of agreement in the initial metrics' definitional dimensions among the buyers, suppliers, and end-users. Of the six metrics reported, there were no metrics with a greater than 50% match in definitional dimensions among the buyers, suppliers, and end-users. These results of phase one of the study identify five of the six metrics as having 20% or fewer matches in common definitional dimensions among the buyers, suppliers, and end-users. The metric technology had zero common definitional dimensions among the participating groups.

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Table 4.7 provides numeric descriptors of the definitional dimensions shared among buyers and suppliers. Table 4.7 also provides: total number of definitional dimensions, matched definitional dimensions, and the percentage of definitional dimensions matched for each of the metrics.

Table 4.7 Shearing Machine Common Definitional Dimensions Among Buyers and Suppliers

	Availability	**Economics**	**Quality/ Performance**	**Safety and Service**	**Supplier Measures**	**Technology**
Definitional Dimension Count B/S/E	4	17	20	16	16	12
Definitional Dimension Match B/S	2	3	4	3	5	0
Match Percentage	50%	18%	20%	19%	31%	0%

When economics and supplier measures in Table 4.7 are compared to the buyers, suppliers, and end-users in Table 4.6, there was an increase in common definitional dimensions related to economics by 6% and supplier measures by 18%. Quality/performance, availability, and technology remain the same. However, the resultant increase still provides less than a 20% match of common definitional dimensions among the buyers and suppliers. Safety and service and quality/performance matching definitional dimensions remained at the same level as the buyers, suppliers, and end-users in Table 4.6. Technology also remained at the same level with zero common definitional dimensions among buyers and suppliers.

Table 4.8 provides numeric descriptors to provide the percentage of the definitional dimensions shared among buyers and end-users. Table 4.8 also provides: total number of

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definitional dimensions, matched dimensions, and the percentage of definitional dimensions matched for each of the metrics.

Table 4.8 Shearing Machine Common Definitional Dimensions Among Buyers and End-Users

	Availability	Economics	Quality/ Performance	Safety and Service	Supplier Measures	Technology
Definitional Dimension Count B/S/E	4	17	20	16	16	12
Definitional Dimension Match B/E	2	2	7	6	4	1
Match Percentage	50%	12%	35%	38%	25%	8%

When Table 4.8 for buyers and end-users was compared to Table 4.6 for the buyers, suppliers, and end-users, the results in Table 4.8 identify a 15% increase in matching definitional dimensions for quality/performance, a 19% increase in safety and service, a 12% increase in supplier measures, an 8% increase in technology; availability and economics remain the same. When Table 4.8 for buyers and end-users was compared to Table 4.7 from the buyers and suppliers, the results in Table 4.8 identify a 6% decrease in matching definitional dimensions for economics, a 15% increase in quality/performance, a 19% increase in safety and service, a 6% decrease in supplier measures, an 8% increase in technology, with the availability metric remaining the same.

Table 4.8 provides results that indicate a low percentage of metrics' definitional dimensions agreement among the buyers and end-users. Of the six metrics reported, there was no metric with a greater than 50% match among the buyers and end-users. These results, using data from phase one of the study, identify four of the six metrics as having a 20% or greater

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match for common definitional dimensions among the buyers and end-users. The Technology metric had the lowest percentage, 8%, in terms of their common definitional dimensions among buyers and end-users, although this was the only match of definitional dimensions in the technology category across all participant groups.

Table 4.9 provides numeric descriptors to provide the percentage of the definitional dimensions that are common among suppliers and end-users. Table 4.9 also provides: total number of definitional dimensions, matched definitional dimensions, and the percentage of definitional dimensions matched for each of the metrics.

Table 4.9 Shearing Machine Common Definitional Dimensions Among Suppliers and End-Users

	Availability	**Economics**	**Quality/ Performance**	**Safety and Service**	**Supplier Measures**	**Technology**
Definitional Dimension Count B/S/E	4	17	20	16	16	12
Definitional Dimension Match S/E	3	4	8	4	2	0
Match Percentage	75%	24%	40%	25%	13%	0%

When comparing Table 4.9 suppliers and end-users to Table 4.6 buyers, suppliers, and end-users, the following differences among common definitional dimensions are identified in Table 4.9: economics increased by 12%, availability increased by 25%, quality/performance increased by 20%, safety and service increased by 6%, supplier measures remained the same, and technology remained the same. The comparison between Tables 4.9, suppliers and end-users, to 4.7, buyers and suppliers, produced the results in Table 4.9: availability increased by 25%, economics increased by 6%, quality/performance increased by 20%, safety and service

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increased by 6%, supplier measures decreased by 18%, and technology remained the same. The comparison between Tables 4.9, suppliers and end-users, and 4.8, buyers and end-users, yielded the results in table 4.9: availability increased by 25%, economics increased by 12%, quality/performance increased by 5%, safety and service decreased by 13%, supplier measures decreased by 12%, and technology decreased by 8%.

Table 4.9 provides results that indicate a low percentage of the initially identified metrics' definitional dimensions agreement among the suppliers and end-users with the exception of availability, which has a 75% match on the common underlying definitional dimensions. Of the six metrics reported, there was no metric with a greater than 75% match among the suppliers and end-users. The results of phase one identify five of the six metrics as having 40% or fewer matches of common definitional dimensions among the suppliers and end-users. Technology had zero common definitional dimensions among the suppliers and end-users.

Table 4.10 provides numeric descriptors to provide the percentage of the definitional dimensions shared among buyers, suppliers, and end-users for the roof control metrics. Table 4.10 also provides: total number of definitional dimensions, matched dimensions, and the percentage of definitional dimensions matched for each of the metrics.

Table 4.10 Roof Control Common Definitional Dimensions Among Buyers/Suppliers/End-Users

	Availability	**Economics**	**Quality/ Performance**	**Safety and Service**	**Supplier Measures**	**Technology**
Definitional Dimension Count B/S/E	4	16	24	32	25	4
Definitional Dimension Match B/S/E	2	1	0	2	4	2
Match Percentage	50%	6%	0%	6%	16%	50%

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Table 4.10 identifies results that indicate a low percentage of initial metric definitional dimension agreement among the buyers, suppliers, and end-users. Of the five metrics reported, there was no metric with a greater than 50% match among the buyers, suppliers, and end-users. The results of phase one identify four of the six metrics as having 16% or fewer matches of common definitional dimensions among the buyers, suppliers, and end-users. Quality/performance had zero common definitional dimensions among the participating groups.

Table 4.11 provides numeric descriptors to provide the percentage of the definitional dimensions that are common among buyers and suppliers for the roof control initial metrics. Table 4.11 identifies: total number of definitional dimensions, matched definitional dimensions, and the percentage of definitional dimensions matched for each of the initial metrics.

Table 4.11 Roof Control Common Definitional Dimensions Among Buyers and Suppliers

	Availability	**Economics**	**Quality/ Performance**	**Safety and Service**	**Supplier Measures**	**Technology**
Definitional Dimension Count B/S/E	4	16	24	32	25	4
Definitional Dimension Match B/S	3	1	0	3	4	3
Match Percentage	75%	6%	0%	9%	16%	75%

When Table 4.11 for buyers and suppliers was compared to Table 4.10 from the buyers, suppliers, and end-users table, the results in Table 4.11 identify a 25% increase in matching definitional dimensions for availability, zero change in economics and quality/performance, a 3% increase in safety and service, and zero change in the initial metric supplier measures.

Table 4.12 provides numeric descriptors to provide the percentage of the dimensions shared among buyers and end-users for the roof control metrics.

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Table 4.12 Roof Control Common Definitional Dimensions Among Buyers and End-Users

	Availability	Economics	Quality/ Performance	Safety and Service	Supplier Measures	Technology
Definitional Dimension Count B/S/E	4	16	24	32	25	4
Definitional Dimension Match B/E	3	1	0	3	4	3
Match Percentage	75%	6%	0%	9%	16%	75%

When Table 4.12 for buyers and end-users was compared to Table 4.10 for the buyers, suppliers, and end-users, the results in Table 4.12 identify zero change in the definitional dimensions for availability, a 7% increase in the dimensions for economics, a 4% increase in the definitional dimensions for quality/performance, zero change in the definitional dimensions for safety and service, and a 4% increase in the definitional dimensions for supplier measures. When Table 4.12 from buyers and end-users was compared to Table 4.11 for the buyers and suppliers, the results in Table 4.12 identify a 25% decrease in matching definitional dimensions for availability, a 7% increase in the definitional dimensions for economics, a 4% increase in the matching definitional dimensions for quality/performance, a 3% decrease in safety and service, and a 4% increase in the matching definitional dimensions for supplier measures.

Table 4.13 provides numeric descriptors to provide the percentage of the definitional dimensions shared among suppliers and end-users for the roof control metrics. Table 4.13 also provides: total number of definitional dimensions, matched definitional dimensions, and the percentage of definitional dimensions matched for each of the metrics.

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Table 4.13 Roof Control Common Definitional Dimensions Among Suppliers and End-Users

	Availability	**Economics**	**Quality/ Performance**	**Safety and Service**	**Supplier Measures**	**Technology**
Definitional Dimension Count B/S/E	4	16	24	32	25	4
Definitional Dimension Match S/E	2	1	1	6	4	2
Match Percentage	50%	6%	4%	19%	16%	50%

When Table 4.13 for suppliers and end-users was compared to table 4.10 from the buyers, suppliers, and end-users, the results in Table 4.13 identify zero change in the matching definitional dimensions for availability and for the economics metrics' definitional dimensions, a 4% increase in the definitional dimensions for quality/performance, a 13% increase in the matching definitional dimensions for safety and service, and zero change in the matching definitional dimensions for supplier measures. When Table 4.13 from suppliers and end-users was compared to Table 4.11 from the buyers and suppliers, the results in table 4.13 identify a 25% decrease in matching definitional dimensions for availability, zero change in the matching definitional dimensions for economics, a 4% increase in the matching definitional dimensions for quality/performance, a 10% increase in the matching definitional dimensions for safety and service, and zero change in the matching definitional dimensions for supplier measures. When Table 4.13 from suppliers and end-users was compared to table 4.12 from the buyers and end-users, the results in Table 4.13 identify zero change in the matching definitional dimensions for availability, a 7% decrease in the matching definitional dimensions for economics, zero change

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in the matching definitional dimensions for quality/performance, a 13% increase in the matching definitional dimensions for safety and service, and a 4% decrease in the matching definitional dimensions for supplier measures.

Research Question Four RQ4

What weight of importance do buyers, suppliers, and end-users assign to the metrics?

Table 4.14 identifies the weight of importance and the Metric Consensus Measure (MCM) score 1-6 (strongly disagree to strongly agree) assigned by the buyers, suppliers, and end-users for the shearing machine. The weight of importance (WOI) identifies the level of importance each group assigns to the identified metrics and definitional dimension list. The Metric Consensus Measure score identifies the participant group score as to the appropriateness of the metric, definitional dimension list, and weight of importance for supplier selection. For example, the buyer assigns a weight of importance of 17% to the metric availability and a Metric Consensus Measure score of 5.57 on a scale of 1-6 (strongly disagree to strongly agree). The end-user assigns a weight of importance of 10% to the metric availability and a Metric Consensus Measure score of 5.43. The supplier assigns a weight of importance of 13% to the metric availability and a Metric Consensus Measure score of 5.20.

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Table 4.14 Shearing machine Metric and Definitional Dimension List

	Buyer		End-User		Supplier	
Metric	**WOI**	**MCM**	**WOI**	**MCM**	**WOI**	**MCM**
Availability Average	17%	5.57	10%	5.43	13%	5.20
Economics Average	17%	5.57	16%	5.71	23%	5.80
Quality/Performance Average	25%	5.71	32%	6.00	21%	5.80
Safety and Service Average	18%	5.71	21%	5.71	16%	5.80
Supplier Measures Average	10%	5.29	8%	5.14	13%	5.20
Technology Average	13%	5.14	13%	5.71	14%	5.80

Table 4.15 identifies the buyers, suppliers, and end-users standard deviation for the metrics and definitional dimensions identified through three phases of interviews with the participants. Standard deviation was used as a descriptive measure as well as to validate the conclusions of this research on whether a consensus has been reached among the buyers, suppliers, and end-users on supplier selection metrics. A lower standard deviation indicates the there was little variability among data points (Babbie, 2004). For the purpose of this study, a small standard deviation was considered to be less than one, and a large standard deviation was considered to be greater than one. A small standard deviation for a metric and its definitional dimensions would indicate that there was a small variability associated with the participants' final agreement levels for the newly defined metric and its underlying definitional dimensions, while a large standard deviation would indicate that there was some amount of difference in opinion between the participants.

One of the purposes of this study was to identify a list of metrics and definitional dimensions for supplier selection at the participant company and to determine if a consensus could be reached between buyers, suppliers, and end-users. For the purpose of this study, a

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consensus was reached with a Metric Consensus Measure score of 3.01 or greater. Table 4.15 indicates there was a consensus among the individual participant groups, and there was minor variability in the weight of importance or Metric Consensus Measure scores among the individual participant groups based on the standard deviation for the weight of importance and the Metric Consensus Measure score. The purpose for using standard deviation descriptively was to identify the variability between participants in the same group and the different participating groups, even though there were only seven participant buyers, seven participant end-users, and seven participant suppliers.

Table 4.15 Shearing Machine Metric and Definitional Dimension List

	Buyer				End-User				Supplier			
	WOI		MCM		WOI		MCM		WOI		MCM	
Metric	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Availability	17%	0.05	5.57	0.53	10%	0.05	5.43	0.53	13%	0.04	5.20	0.45
Economics	17%	0.05	5.57	0.53	16%	0.07	5.71	0.49	23%	0.04	5.80	0.45
Quality/ Performance	25%	0.06	5.71	0.49	32%	0.11	6.00	0.00	21%	0.02	5.80	0.45
Safety and Service	18%	0.04	5.71	0.49	21%	0.07	5.71	0.49	16%	0.04	5.80	0.45
Supplier Measures	10%	0.04	5.29	0.49	8%	0.04	5.14	0.69	13%	0.04	5.20	0.45
Technology	13%	0.05	5.14	0.69	13%	0.06	5.71	0.49	14%	0.05	5.80	0.45

Table 4.16 identifies the cumulative weight of importance and the cumulative Metric Consensus Measure score 1-6 (strongly disagree to strongly agree) assigned by the buyers, suppliers, and end-users for the shearing machine. The weight of importance identifies the cumulative level of importance the groups assign to the identified metric and definitional dimension list. The Metric Consensus Measure score identifies the cumulative group score as to

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the appropriateness of the metric, its corresponding definitional dimension list, and the subsequent weight of importance as it pertains to supplier selection.

When summarizing the information in Table 4.14 into one group (as identified in Table 4.16), the following differences in Table 4.16 are identified for the weight of importance: the metric availability for the buyer decreased by 3%, for the end-user was increased by 4%, and for the supplier was increased by 1%; the metric economics for the buyer was increased by 2%, for the end-user was increased by 3%, and for the supplier decreased by 4%; the metric quality/performance for the buyer was increased by 1%, for the end-user decreased by 6%, and for the supplier was increased by 5%; the metric safety and service for the buyer was the same, for the end-user decreased by 3%, and for the supplier was increased by 2%; the metric supplier measures for the buyer was the same, for the end-user was increased by 2%, and for the supplier decreased by 4%; and finally the metric technology for the buyer was the same, for the end-user was the same, and for the supplier decreased by 1%.

When summarizing the information in Table 4.14 into one group (as identified in Table 4.16), the following differences in Table 4.16 are identified for the Metric Consensus Measure score: the metric availability for the buyer decreased by .37, for the end-user decreased by .03, and for the supplier was increased by .20; the metric economics for the buyer was increased by .13, for the end-user decreased by .01, and for the supplier was increased by .50; the metric quality/performance for the buyer was increased by .13, for the end-user decreased by .16, and for the supplier was increased by .04; the metric safety and service for the buyer decreased by .03, for the end-user was increased by .60, and for the supplier was increased by .54; the metric supplier measures for the buyer decreased by .08, for the end-user was increased by .07, and for

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the supplier was increased by .01; the metric technology for the buyer was increased by .41, for the end-user decreased by .16, and for the supplier decreased by .25.

Table 4.16 Shearing Machine Metric and Definitional Dimension List, Buyer/Supplier/End-User

Metric	WOI	MCM
Availability Average	14%	5.40
Economics Average	19%	5.70
Quality/Performance Average	26%	5.84
Safety and Service Average	18%	5.74
Supplier Measures Average	10%	5.21
Technology Average	13%	5.55

Table 4.17 identifies the standard deviation for the cumulative weight of importance and the cumulative Metric Consensus Measure score 1-6 (strongly disagree to strongly agree) assigned by the buyers, suppliers, and end-users for the shearing machine. The weight of importance identifies the cumulative level of importance the groups assign to the identified metric and definitional dimension list. The Metric Consensus Measure score identifies the cumulative group score as to the appropriateness of the metric, its corresponding definitional dimension list, and the subsequent weight of importance as it pertains to supplier selection.

When summarizing the standard deviation information in Table 4.15 into one group (as identified in Table 4.17), the following differences in Table 4.17 are identified for the weight of importance standard deviation: the metric availability for the buyer was identical, for the end-user it was identical, and for the supplier it was increased by .01; the metric economics for the buyer was increased by .01, for the end-user was increased by .01, and for the supplier was it increased by .02; the metric quality/performance for the buyer was increased by .03, for the end-user decreased by .02, and for the supplier was increased by .07; the metric safety and service for

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the buyer was increased by .02, for the end-user decreased by .01, and for the supplier was increased by .02; the metric supplier measures for the buyer was identical, for the end-user was identical, and for the supplier was identical; and finally, the metric technology for the buyer was identical, for the end-user decreased by .01, and for the supplier was identical.

When summarizing the information in Table 4.15 into one group (as identified in Table 4.17), the following differences in Table 4.17 are identified for the Metric Consensus Measure score: the metric availability for the buyer decreased by .02, for the end-user decreased by .02, and for the supplier was increased by .06; the metric economics for the buyer decreased by .05, for the end-user decreased by .01, and for the supplier was increased by .03; the metric quality/performance for the buyer decreased by .12, for the end-user was increased by .37, and for the supplier decreased by .08; the metric safety and service for the buyer decreased by .04, for the end-user decreased by .04, and for the supplier was identical; the metric supplier measures for the buyer was increased by .05, for the end-user decreased by .15, and for the supplier was increased by .09; the metric technology for the buyer decreased by .08, for the end-user was increased by .12, and for the supplier was increased by .16.

Table 4.17 Shearing Machine Metric and Definitional Dimension List, Buyer/Supplier/End-User

	WOI		**MCM**	
Metric	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Availability	14%	0.05	5.42	0.51
Economics	18%	0.06	5.68	0.48
Quality/ Performance	26%	0.09	5.84	0.37
Safety and Service Average	19%	0.06	5.74	0.45
Supplier Measures	10%	0.04	5.21	0.54
Technology	13%	0.05	5.53	0.61

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Table 4.18 identifies the weight of importance and the Metric Consensus Measure score 1-6 (strongly disagree to strongly agree) assigned by the buyers, suppliers, and end-users for the roof control products. The weight of importance identifies the level of importance each group assigns to the identified metric and definitional dimension list. The Metric Consensus Measure score identifies the participant group score as to the appropriateness of the metric, definitional dimension list, and weight of importance for supplier selection. For example, the buyer assigns a weight of importance of 19% to the metric economics and a Metric Consensus Measure score of 5.57 on a scale of 1-6 (strongly disagree to strongly agree). The end-user assigns a weight of importance of 20% to the metric economics and a Metric Consensus Measure score of 5.71. The supplier assigns a weight of importance of 16% to the metric economics and a Metric Consensus Measure score of 5.75.

Table 4.18 Roof Control Metric and Definitional Dimension List, Buyer/Supplier/End-User

	Buyer		**End-User**		**Supplier**	
Metric	**WOI**	**MCM**	**WOI**	**MCM**	**WOI**	**MCM**
Availability Average	18%	5.57	16%	5.43	15%	5.75
Economics Average	19%	5.57	20%	5.71	16%	5.75
Quality/Performance Average	25%	5.57	32%	6.00	26%	6.00
Service and Design Average	23%	5.57	18%	5.43	24%	5.50
Supplier Measures Average	15%	5.14	12%	5.00	19%	5.25

Table 4.19 identifies the buyers, suppliers, and end-users' standard deviation for the metrics and definitional dimensions identified for the roof control products through three phases of interviews with the participants. Standard deviation was used descriptively and to validate the conclusions of this research for the roof control products on whether a consensus had been reached among the buyers, suppliers, and end-users on supplier selection metrics. A small

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standard deviation for a metric and its definitional dimensions would indicate that there was a small variability associated with the participants' final agreement level for the newly defined metric and its underlying definitional dimensions, while a large standard deviation would indicate that there was some amount of difference in opinion among the participants.

Table 4.19 Roof Control Metric and Definitional Dimension List, Buyer/End-User/Supplier

	Buyer				End-User				Supplier			
	WOI		MCM		WOI		MCM		WOI		MCM	
Metric	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Availability	18%	0.05	5.57	0.53	21%	0.09	5.43	0.53	20%	0.96	5.25	0.96
Economics	16%	0.07	5.43	0.53	33%	0.10	5.71	0.00	15%	0.50	5.25	0.50
Quality/ Performance	16%	0.07	5.43	0.53	25%	0.07	6.00	0.49	16%	0.82	5.00	0.82
Service and Design	19%	0.05	5.71	0.49	23%	0.08	5.43	0.53	9%	0.04	5.25	0.50
Supplier Measures	21%	0.02	5.86	0.38	19%	0.10	5.00	0.53	19%	0.50	5.25	0.50

Table 4.20 identifies the cumulative weight of importance and the cumulative Metric Consensus Measure score 1-6 (strongly disagree to strongly agree) assigned by the buyers, suppliers, and end-users for the roof control products. The weight of importance identifies the cumulative level of importance the groups assign to the identified metric and definitional dimension list. The Metric Consensus Measure score identifies the cumulative group score as to the appropriateness of the metric, its corresponding definitional dimension list, and the subsequent weight of importance as it pertains to supplier selection.

When summarizing the information in Table 4.18 into one group (as identified in Table 4.20), the following differences in Table 4.20 are identified for the weight of importance: the metric availability for the buyer decreased by 1%, for the end-user was increased by 1%, and for the supplier was increased by 2%; the metric economics for the buyer was identical, for the end-

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user decreased by 1%, and for the supplier was increased by 3%; the metric quality/performance for the buyer was increased by 3%, for the end-user decreased by 4%, and for the supplier was increased by 2%; the metric service and design for the buyer decreased by 1%, for the end-user was increased by 4%, and for the supplier decreased by 2%; and finally the metric supplier measures for the buyer was the same, for the end-user was increased by 3%, and for the supplier decreased by 4%.

When summarizing the information in Table 4.18 into one group (as identified in Table 4.20), the following differences in Table 4.20 are identified for the Metric Consensus Measure score: the metric availability for the buyer was increased by .01, for the end-user decreased by .15, and for the supplier decreased by .17; the metric economics for the buyer was increased by .11, for the end-user decreased by .03, and for the supplier was increased by .07; the metric quality/performance for the buyer decreased by .29, for the end-user decreased by .14, and for the supplier decreased by .14; the metric service and design for the buyer decreased by .07, for the end-user decreased by .07, and for the supplier was identical; and finally the metric supplier measures for the buyer decreased by .01, for the end-user was increased by .13, and for the supplier decreased by .12.

Table 4.20 Roof Control Metric and Definitional Dimension List, Buyer/End-User/Supplier

Metric	WOI	MCM
Availability Average	17%	5.58
Economics Average	19%	5.68
Quality/Performance Average	28%	5.86
Service and Design Average	22%	5.50
Supplier Measures Average	15%	5.13

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Table 4.21 identifies the standard deviation for the cumulative weight of importance and the cumulative Metric Consensus Measure score 1-6 (strongly disagree to strongly agree) assigned by the buyers, suppliers, and end-users for the roof control products. The weight of importance identifies the cumulative level of importance the groups assign to the identified metric and definitional dimension list. The Metric Consensus Measure score identifies the cumulative group score as to the appropriateness of the metric, its corresponding definitional dimension list, and the subsequent weight of importance as it pertains to supplier selection.

When summarizing the standard deviation information in Table 4.19 into one group (as identified in Table 4.21), the following differences in Table 4.21 are identified for the weight of importance standard deviation: the metric availability for the buyer was increased by .01, for the end-user it decreased by .03, and for the supplier it decreased by .90; the metric economics for the buyer decreased by .02, for the end-user was increased by .05, and for the supplier was it decreased by .45; the metric quality/performance for the buyer was increased by .01, for the end-user was increased by .01, and for the supplier decreased by .74; the metric service and design for the buyer was increased by .03, for the end-user was identical, and for the supplier was increased by .04; and finally, the metric supplier measures for the buyer was increased by .03, for the end-user decreased by .05, and for the supplier decreased by .45.

When summarizing the information in Table 4.19 into one group (as identified in Table 4.21), the following differences in Table 4.21 are identified for the Metric Consensus Measure score: the metric availability for the buyer decreased by .02, for the end-user decreased by .02, and for the supplier decreased by .45; the metric economics for the buyer decreased by .04, for the end-user was increased by .05, and for the supplier decreased by .01; the metric quality/performance for the buyer decreased by .15, for the end-user decreased by .11, and for

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the supplier decreased by .44; the metric service and design for the buyer was increased by .02, for the end-user decreased by .02, and for the supplier was increased by .01; and finally, the metric supplier measures for the buyer was increased by .20, for the end-user was increased by .05, and for the supplier was increased by .08.

Table 4.21 Roof Control Metric and Definitional Dimension List, Buyer/End-User/Supplier

	WOI		MCM	
Metric	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Availability	17%	0.06	5.56	0.51
Economics	19%	0.05	5.67	0.49
Quality/ Performance	28%	0.08	5.83	0.38
Service and Design	21%	0.08	5.50	0.51
Supplier Measures	15%	0.05	5.11	0.58

Chapter Summary

This three-phase interview process using the Delphi Method was completed for a piece of capital equipment, a shearing machine, and for a MRO product, roof control. The study included 21 participants: seven buyers, seven suppliers, and seven end-users. These participants had a total of 576 years of experience in their respective areas of expertise. Through this study, metrics for each of these items were identified as were their associated underlying dimensions. No differences between the identified metrics were found for any of the participants. However, differences in the underlying definitional dimensions that comprise the metrics were identified between buyers, suppliers, and end-users. Participants weighted the importance of the metrics and a consensus among the different participant groups was reached with regard to the metrics and corresponding definitional dimensions. All participants agreed that the process used for this study, if implemented, can add value to supplier selection at the participating company.

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CHAPTER 5: DISCUSSION

Overview

This chapter provides a discussion of the findings identified through this research project. The first section provides a discussion of the findings as they relate to the research questions and their importance to the literature. This section also provides a discussion on whether a consensus was reached on supplier selection metrics and their definition among the buyers, suppliers, and end-users. The second section discusses the limitations identified in this study. The third section identifies areas for potential future studies. The fourth section discusses the concluding remarks of the researcher.

Research Question One RQ1

What metrics are being used for decision support in strategic sourcing supplier selection?

Metrics in its most basic form are measurements; in business, metrics allow the choice of a given process, item, or information to be used as a quantification of success or failure as defined by that business (Stork & Morgan, 1999). Metrics as part of supply management are easy to accept and understand; however, it must be realized that a metric can be unique to a given organization based on individual requirements such as quality that can have different definitions for different companies (Duffy, 2006, p. 34).

Supplier selection is a part of supply chain management and strategic sourcing. A part of supplier selection comes from an understanding of the buyer's knowledge that collaboration in competition must be applied by all parties involved (Cavinato, et al., 2006; Spekman, Kamauff, & Myhr 1998). Increasing cost for both the suppliers and buyers in response to a global demand

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for limited resources has made supplier selection a key priority for supply chain management (Trent & Monczka, 1998). The supply chain management function is required to consider all areas of the supply chain, and how each impacts the equipment or product requirements, and how each can add value to the end-user in making the supplier selection (Davis, 1993; Mabert & Venkataramanan, 1998). One approach to collaboration is using a clear method of supplier selection, such as defining what metrics are to be used in supplier selection. Precise metric definitions allow all participants -- buyers, suppliers, and end-users -- to have clear expectations for requirements of equipment, services, or products prior to strategic sourcing supplier selection. This method does allow for greater accountability for buyers, suppliers, and end-users. Having a clear method for supplier selection also helps the sourcing company to meet the requirements of SOX.

Section 404 of SOX requires executive management of a company to approve and attest to the effectiveness of the internal key controls established for financial reporting. One requirement of internal key controls is that a company must have a written process that is validated and tested by external and internal auditors on an annual basis. The process must be repeatable, definable, and auditable for reporting as required by SOX. An example of internal key controls would be a clear understanding of how the company decided to expend the approved capital and operating budget for capital projects and required commodities for the day-to-day operation of the company.

This study identified the metrics used for supplier selection among the buyers, suppliers, and end-users. A case study was completed using a Delphi Method with three phases to collect the necessary data. One question asked of the participants was what metrics are being used for supplier selection for a shearing machine and the MRO commodity roof control. The metrics

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were categorized by participant group (buyer, supplier, and end-user) and broken into either the shearing machine or MRO commodity roof control products. This study brought the metric from a macro level to a micro level by identifying multiple, specific metrics for a particular piece of equipment and a defined MRO commodity group.

The buyers, suppliers, and end-users defined and agreed to a list of metrics through the iterative Delphi Method. The metrics for the shearing machine supplier selection included: availability, economics, supplier measures, quality/performance, safety and service, and technology. In the same manner buyers, suppliers, and end-users defined and agreed to a list of metrics through an iterative Delphi Method, for the roof control product selection including: availability, economics, quality/performance, service and design, and supplier measures.

The buyer participant responses to this process were all of a positive view, and the buyers felt that it was critical to have some way of measuring the choice of suppliers for key areas of the company's business. Key areas the buyers spoke about were receiving a return on investment for decisions made in supplier selection and not having the ability to easily change once a decision is made in the areas of roof control or shearing machine selection. The example from buyer one below identifies the critical nature of doing an in-depth analysis of the information available through such a supplier selection process:

> *Buyer one*: "We definitely need to do that and I went into that a little bit already, but the why is because we can always do better and we have some minor failures in selection but once the selection is made it's pretty tough to change your mind, especially when you install it 10 miles underground. It's a very important process, it's not – a lot of times you don't have a second chance and investments

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> – sometimes the investment is very high – so the real critical part is doing the analysis and putting the intelligence together before, again, the selection is made."

The end-user responses to the question were very similar to the buyer responses; it is very important to make the correct decision in supplier selection for critical areas of the mining process. The end-users expressed the need for quality and performance measures to be put in place to make sure the profitability of their locations could be maintained. The end-users expressed their concern as they are judged on their profit center cost and production, and therefore they need to be included in the supplier selection process. The end-user comment below expresses the need for cross functional efforts to achieve the best results:

> *End-user one*: "I think there's no question to having metrics. I mean if we didn't have the metrics on some of the things we discussed here and you didn't rank those things, probably if we needed a roof bolt we'd go out and find the cheapest roof bolt and that's the one we'd buy. Going back to the shearing machine, you can buy some – what I'm going to call some known problems at a lower cost, but the fact is it doesn't get the job done. So without these metrics – supply chain management and everyone working together you'd never survive in my mind."

The supplier response looked at supplier selection metrics in a couple of ways. First, suppliers believe that with a process such as this, they can be judged fairly for what value their company has been able to deliver not only for current requirements, but also on a historical basis. Secondly they feel that a clear process such as what was done in this study allows the buyer and end-user to deal with potential areas of concern up front and not after the decision has been made. Also they feel a supplier can add better value to the end-user through a good supplier selection process as stated by the supplier example below:

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Supplier one: "Yes, there absolutely is for several reasons. Ultimately in a free market economy suppliers and all areas of the company want to have the same thing; they want to provide economic value for the companies they work for in general, whether it be a coal company or a coal equipment company and if you're supplying the goods that meet a common set of definitional dimensions you should actually both be able achieve that goal of providing value for both companies. Usually you find when you talk through things that everybody should have the same set of definitional dimensions and therefore the same set of ways of measuring a transaction. So, yes I think it's the right thing to do. It's just not always very easy to achieve and I think it's often not achieved because of various parties, whether it's internally between operations and maintenance and purchasing or whether it's between the buyer and supplier there isn't a common understanding of what those metrics are so people don't necessarily understand what it is that they're being measured on. I think it's also important because you have to have a way once the transaction happens, two or three years down the road you can look back at that transaction, back to the metrics that you used to make that selection and say was that good or was it a bad transaction so you learn from it the next time so you know whether to improve on it or say, 'that was pretty good.' There has to be a way of looking back at historically to see whether or not you made a good decision."

By answering the research question, what are the metrics used in strategic sourcing supplier selection at the participant company, this study added to the body of knowledge in supply chain management in two ways. First, this study identified the lack of consensus among

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the stakeholders in the strategic sourcing supplier selection process and its corresponding need to move from a macro level view of metric to a micro level view of metric requirements across all stakeholder groups in the supplier selection process. Second, the applied nature of this research allowed for stakeholder input as to the process' perceived value in better defining supplier selection metrics. This is exemplified by participants' responses to the question: do you see value in this process and in having supplier selection metrics?

Research Question Two RQ2

Do the metrics differ among buyers, suppliers, and end-users?

An element of this research was also to determine if the metrics for supplier selection were the same among the buyers, suppliers, and end-users. One key factor to meeting customer requirements is supplier selection, a component of which requires appropriate supplier selection criteria to meet the operational requirements of the product or equipment (Hou & Su, 2006; Ndubisi, Jantan, Hing, & Ayub, 2005). This current study actually implemented this strategy using the Delphi Method and reached a consensus on strategic sourcing supplier selection metrics. Initially, participants provided a list of metrics required for supplier selection and shared their thoughts on similarities and differences expected among the participating groups.

Researchers (Ndubisi, Jantan, Hing, & Ayub, 2005; Trent & Monczka, 1998) suggest that supplier involvement at the early stages of understanding needed requirements can lead to delivering the greatest value to operations success, and therefore understanding the metrics used in supplier selection can help facilitate this process. Each of the groups participating in the current research agreed that there existed a need to identify and define metrics for supplier selection and felt that they were mostly aware of what the metrics were; however, all groups also

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felt this study was required to create a clearly defined set of metrics for the equipment and MRO product in this study.

For example, one of the participants from the buyers thought that the metrics were the same, but were just viewed differently. This theme is consistent among all the buyer participants. Buyer one said:

> "I think that the metrics are the same. I think the weighting and the emphasis on each metric may be different and specific areas that are involved in the selection process - whether it be engineering or procurement –and some of the safety groups – whoever gets and the maintenance groups – whoever gets involved – are going to prioritize their area a littler bit higher than the general view that we've taken, but ultimately all the metrics need to be considered before the end selection is made and if they are considered then the high probability of selecting the most cost effective and safest and most productive will be made. I think they're the same; it's just how much emphasis you put on each one. That's why we use more than one group to decide – get everyone's input."

The buyer group felt the need for knowing what the supplier selection metrics were, and as stated, it is important to include input from all groups as well. The buyer also stated that failure to have input from all groups could have a negative consequence on cost and safety at the operations and thereby to the entire company.

The end-user groups' concepts of metrics were not that different from the buyer groups' concepts; a general idea of metrics exists, but not a clearly defined list. End-user one said:

> "They're the same. I think the list would be similar, but sometimes how the list is prioritized may be a little bit different and that's understandable. I think the user

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is looking at performance, availability. Whatever you're purchasing – how does it do for you when you put it into use? Does the shearing machine cut more coal than the other shearing machine? Does the roof bolt go in without a hitch and does it support the roof properly? When you move on to the buyer stage, those guys are more interested in price because they're not the end-user. A lot of times they don't see what's going on when you're implementing it – when they're buying it, they don't get to see that, so they don't know that the shearing machine is two minutes per pass quicker on each end. They don't know that."

The end-users also felt the list of metrics would be the same; however, their prioritization of the metrics on that list was a group specific order based on each specific group's view and the requirements for their jobs.

And finally, along with the buyers and end-users, the suppliers also had a similar view of supplier selection metrics. Supplier one said:

> "I think they're all close. All this stuff that I mentioned to you – quality, service, I think that could apply to you guys and to all these folks. Maybe just in a little different light. Roof control products would be more important in terms of safety than something else you buy, like rail or something. Certain products are more important and should be rated higher on the post. Roof control products have to be number one for safety. So, yes, I think these things are very valuable. I think they probably apply to you and all the others, just in different ways."

The suppliers, just as the buyers, held the view that the supplier selection metrics are the same; however, they are perceived differently among the groups. The suppliers believe metrics are

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viewed differently because each group is looking at their individual areas of responsibility and not at the buyer, supplier, or end-user group as a whole.

Research Question Three RQ3

Do the definitions of the metrics differ among buyers, suppliers, and end-users?

Cross functional efforts in organizations began to develop in the 1990s and continue today to facilitate decision making that supports the greatest return on a company's investments (Burt, et al. 2003; Cavinato, et al., 2006; Trent & Monczka, 1998). Part of this current research was to determine if differences existed in the metrics' definitions between the buyers, suppliers, and end-users. Potential differences were examined using the Delphi Method with three phases of interviews. Trent and Monczka's (1998) discussion of product-based metrics provides an effective tool to measure supplier effectiveness. However, to maximize the benefit of product-based metrics, the metrics must be defined consistently among buyers, suppliers, and end-users in order to facilitate effective communication in cross-functional collaborative relationships. One technique that can result in consistent definition across these stakeholder groups is metric identification and definition using the Delphi Method.

The first interview was used to identify the metrics and definitions each participant group felt were necessary for supplier selection for the MRO commodity roof control products and the capital equipment item shearing machine. The first phase's interview data were used to answer the research question three: do the definitions of the metrics differ among buyers, suppliers, and end-users? The interviews also were used to identify the common definitional dimensions among buyers, suppliers, and end-users.

The phase two interviews gave each participant the opportunity to review the list of

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metrics and definitions and recommend changes. These phase two interviews were used to begin the exploration of a possible consensus among buyers, suppliers, and end-users on the list of metrics and their definitions. The phase two interviews also required participants to assign Metric Consensus Measure scores and a weight of importance to each of the metrics.

The phase three interviews provided participants from all three groups the opportunity to identify final Metric Consensus Measure scores for each adjusted metric, and its corresponding weight of importance, for each metric used in supplier selection. The Metric Consensus Measure scores were used to determine the extent to which a consensus was reached among buyers, suppliers, and end-users, as discussed in Chapter 3. Weight of importance is discussed further for research question four.

The phase one interview process for the shearing machine identified six metrics utilized for supplier selection: availability, economics, quality/performance, safety and service, supplier measures, and technology. However, when the participant groups (buyer, supplier, end-user) defined the metrics with definitional dimensions, differences were apparent among the groups. More importantly, there was very little commonality among buyers, suppliers, and end-users when the metrics were defined in more detail (definitional dimension) and were reviewed and compared among the participant groups.

The first definitional dimensions reviewed by the groups of participants were those assigned to the availability metric; there were a total of four definitional dimensions used by the buyers, suppliers, and end-users to define the metric. Availability actually had the largest percentage of agreement with respect to the definitional dimensions among the participant groups. For the availability metric, there was a 50% match among buyers, suppliers, and end-users (21 of 21 participants); however, there were a total of only four definitional dimensions

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used to define the metric availability. The availability metric among buyers and suppliers (14 of 21 participants), and buyers and end-users (14 of 21 participants), had a 50% match on common definitional dimensions between these groups. However, the group by group comparison between supplier and end-user (14 of 21 participants) yielded a 75% match of common definitional dimensions. This indicates there might be a closer relationship between the supplier and end-user than the other comparative groups studied. This also supports participants' claims that the definitions of the metrics are not the same between groups.

The next metric reviewed for common definitional dimensions across participant groups was the economics metrics. The economics metric had a total of 17 definitional dimensions assigned by the buyers, suppliers, and end-users for the purpose of defining the metric for supplier selection. When the list of definitional dimensions was compared among buyers, suppliers, and end-users, there were only two common definitional dimensions. This resulted in a 12% match among these stakeholders. A comparison between the buyers and end-users revealed that the matching definitional dimensions did not increase, but remained the same as the buyers, suppliers, and end-users. The comparison between the buyers and suppliers revealed 18% (3) common definitional dimensions, which is a 6% increase as compared to the buyers, suppliers, and end-users. The comparison between suppliers and end-users identified 24% (4) match in common definitional dimensions, which is a 12% increase as compared to the buyers, suppliers, and end-users. These results are similar to those of the metric availability, and indicate that there may be a better understanding of the other's perspective between the suppliers and end-users than either group has with the buyers. These results also indicate that there was a difference in the manner in which each of the participating groups defines the given metrics.

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The next metric reviewed was the quality/performance metric. The quality/performance metric had a total of 20 definitional dimensions identified by the buyers, suppliers, and end-users to define the metric. The comparison between buyers, suppliers, and end-users identified a 20% (4) match in common definitional dimensions. The comparison between buyers and suppliers found that the match in common definitional dimensions was the same as that reported for the buyers, suppliers, and end-users. The comparison between buyers and end-users found a 35% (7) match in common definitional dimensions among these two groups. The comparison between suppliers and end-users found a 40% (8) match in the common definitional dimensions used by these two groups. These results support the previous finding, that there is a closer relationship among the suppliers and end-users than any of the other user groups. Similarly, these results also support that there is a difference in how each of the participating groups defines the given metrics.

The next metric reviewed was safety and service. Safety and service had a total of 16 definitional dimensions identified among the buyers, suppliers, and end-users to define the metric. The comparison between buyers, suppliers, and end-users identified a 19% (3) match for common definitional dimensions among the participant groups. The comparison between buyers and suppliers identified the same common definitional dimensions as those found when comparing the buyers, suppliers, and end-users. The comparison between buyers and end-users identified a 38% (6) match of common definitional dimensions among these two groups. The comparison between suppliers and end-users identified four or a 25% match of common definitional dimensions among these two groups. This suggests that there is a closer relationship between the buyer and end-user than the other groups listed. This also shows that the definitions are not the same among the buyers, suppliers, and end-users. However, the match of common

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definitional dimensions between end-user and supplier was strong and also indicates that there may be a strong relationship between these two groups.

The next metric reviewed for common definitional dimensions across groups was supplier measures. The supplier measures metric had a total of 16 definitional dimensions identified by the buyers, suppliers, and end-users for defining the metric. A comparison of the definitional dimensions between buyers, suppliers, and end-users identified a 13% (2) match in common definitional dimensions used to define the metric. The comparison between buyers and suppliers identified a 31% (5) match in common definitional dimensions used to define the metric across these two groups. The comparison between buyers and end-users yielded a 25% (4) match in common definitional dimensions used to define the metric among these two groups. The comparison between suppliers and end-users showed a 13% (2) match in common definitional dimensions used to define the metric among these two groups. These comparisons suggest that there may be a closer relationship between the buyer and supplier than the other groups listed. Additionally, the variability in commonly selected dimensions across the groups also indicates the definitions are not the same among the buyers, suppliers, and end-users.

The final metric reviewed for common definitional dimensions across groups was technology. The technology metric had a total of 12 definitional dimensions identified by buyers, suppliers, and end-users for defining the metric. The comparison between buyers, suppliers, and end-users failed to identify any common definitional dimensions used to define the metric among these three groups. Similarly, the comparison between buyers and suppliers, and suppliers and end-users also failed to identify any matching definitional dimensions for defining the metric among these groups. The comparison between buyers and end-users showed an 8% (1) match in common definitional dimensions used to define the metric among these two groups. The result

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of the comparisons provides a strong indication there is a complete disconnect in defining the metric technology among buyers, suppliers, and end-users.

The comparisons, done across the buyer, supplier, and end-user groups, identify for the six metrics, the key areas where a shared understanding could be hampered by participants ' lack of consistency in clearly explicating each of the metric's underlying definitional dimensions with members of the other groups.

Shearing Machine

The phase one interviews for the shearing machine identified six common metrics: availability, economics, quality/performance, safety and service, supplier measures, and technology. Any metric commonality among the buyers, suppliers, and end-users ended at this level of analysis. There was a limited amount of commonality in terms of specifically defining the metrics. However, looking at the group of metrics as a whole showed that there was a difference in how the metrics were defined among the participating groups. One major finding that is outside the scope of this research is that there was a stronger relationship between any two groups than there was among the three groups together. Correspondingly, there was a closer match between the suppliers and end-users than between any of the other groups. Such gaps between stakeholders' understanding of metrics at the definitional level can result in a misinformed cross-functional process, rather than a unified one called for by Ndubisi, Jantan, Hing, and Ayub (2005) and Trent and Monczka (1998), to see desired results in strategic sourcing supplier selection.

The phase one interview process for the MRO commodity roof control products identified five metrics utilized for supplier selection: availability, economics, quality/performance, service and design, and supplier measures. However, when the participant

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groups defined these metrics with definitional dimensions, the results clearly indicated a difference among the groups. There was little in common among buyers, suppliers, and end-users when the definitional dimensions for each metric were reviewed and compared among the participant group responses.

The first definitional dimensions reviewed were those assigned to availability; there were a total of four definitional dimensions used by the buyers, suppliers, and end-users to define the metric. The availability metric actually had the largest percentage of common definitional dimensions among the participant groups. There was a 50% match among buyers, suppliers, and end-users; however, there were only a total of four definitional dimensions used to define the metric availability among these three groups. The common definitional dimensions among buyers and end-users did not improve the metrics match, which remained at a 50% match among these two groups. However, the buyers and suppliers comparison resulted in a 75% (3) match of common definitional dimensions among these two groups. This suggests that there might be a closer relationship between the buyers and suppliers than between the other groups. This also indicates the definitions are not the same among the buyers, suppliers, and end-users.

The next metric reviewed for common definitional dimensions across groups was economics. The economics metric had a total of 16 definitional dimensions identified by the buyers, suppliers, and end-users to define the metric among the three groups. The comparison between buyer, supplier, and end-user groups identified a 6% (1) match of common definitional dimensions among the paired groups (buyer/supplier; buyer/end-user; supplier/end-user). The comparison between buyers and suppliers, and suppliers and end-users, had the same common definitional dimensions as the buyers, suppliers, and end-users to define the metric. The comparison between the buyers and end-users identified a 13% (2) match of common

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definitional dimensions to define the metric among these two groups. This is a clear indication that the metrics are defined differently among the buyers, suppliers, and end-users.

The next metric reviewed for common definitional dimensions was quality/performance. The quality/performance metric had 24 definitional dimensions identified by the buyers, suppliers, and end-users to define the metric among these three groups. The comparison between buyers, suppliers, and end-users failed to identify any common definitional dimensions used to define the metric among these three groups. The comparison between buyers and suppliers also failed to identify any common definitional dimensions among these two groups. The comparisons done between buyers and end-users, and suppliers and end-users, identified a 4% (1) match for common definitional dimensions used to define the metric among these two groups. This may indicate that the metrics are defined differently among the buyers, suppliers, and end-users.

Another metric reviewed for common definitional dimensions was service and design. The service and design metric had 32 definitional dimensions identified by the buyers, suppliers, and end-users. The comparison between buyer, supplier, and end-user groups identified a 6% (2) match in common definitional dimensions used to define the metric among the paired groups (buyer/supplier; buyer/end-user; supplier/end-user). The comparison between the buyers and suppliers identified a 9% (3) match of common definitional dimensions used to define the metric among these two groups. The comparison between buyers and end-users identified a 6% (2) match of common definitional dimensions used to define the metric among these two groups. The comparison between suppliers and end-users identified a 19% (6) match of common definitional dimensions used to define the metric among these two groups. These results show that there is a significant difference in how each group defines the metrics.

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The final metric reviewed for common definitional dimensions was supplier measures. The supplier measures metric had a total of 25 definitional dimensions identified by the buyers, suppliers, and end-users to define the metric among these three groups. The comparison between the buyers, suppliers, and end-users identified a 16% (4) match of common definitional dimensions used to define the metric among these three groups. The comparison between buyers and suppliers, and suppliers and end-users, identified the same number and percentage 20% (5) of common definitional dimensions as the buyers, suppliers, and end-users used to define the metric among these groups. These findings suggest that there is a substantial difference in how each group defines the metrics. The comparisons between the various groups indicate the five metrics (availability, economics, quality/performance, service and design, and supplier measures) are defined differently among the buyers, suppliers, and end-users.

The phase one interviews for the MRO commodity roof control products identified five common metrics (availability, economics, quality/performance, service and design, and supplier measures). The metric commonality among the buyers, suppliers, and end-users ended there. There was an average of a 50% or less match in common definitional dimensions for metrics among these groups. However, when looking at the group of metrics as a whole, the participants provided a clear indication that there is a difference in how metrics are defined across each of the participating groups. The one predominant finding indicated that there appears to be a stronger relationship among any two groups rather than the three groups together, with the closest match being between the supplier and end-user than any of the other two groups. The literature indicates that with collaboration between the supplier and buyer, there is a better opportunity to provide the end-user with the products needed for operations (Harrison, Lee, & Neale, 2005). The phase two and three face-to-face individual interviews addressed this need.

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The phase two and three interviews also gave the buyers, suppliers, and end-users the opportunity to review and adapt the complete list of metrics and their corresponding definitional dimensions for both the capital equipment shearing machine and the MRO commodity roof control products. From this information the participants recommended adjustments and/or changes they would like to see to the list of metrics and definitional dimensions. Any changes or adjustments made were based on the criteria set in Chapter 3. Through these two interviews, the buyers, suppliers, and end-users assigned on a scale of 1-6 (strongly disagree to strongly agree) a Metric Consensus Measure score to identify their agreement level as to the appropriateness of the metrics and definitional dimensions for supplier selection.

For the capital equipment shearing machine, the results indicate that there was greater agreement on and less variability within each of the metrics. The metrics and definitional dimensions along with the assigned Metric Consensus Measure score were: availability 5.40, economics 5.70, quality/performance 5.84, safety and service 5.74, supplier measures 5.21, and technology 5.55. The consensus is evidenced by the Metric Consensus Measure average of over 5.00 being reached among the buyers, suppliers, and end-users for each of the metrics and their corresponding definitional dimensions. There was also little variability among the scores of the individual groups (SD Buyer = .54, SD Supplier = .45, and SD End-User = .45) or the average of all the groups (SD = .49).

Similarly, the Metric Consensus Measure scores were also calculated for the MRO commodity roof control products. The final list is the metrics and definitional dimensions with the combined average Metric Consensus Measure as assigned by the buyers, suppliers, and end-users for the MRO commodity roof control products. The metrics and definitional dimensions along with the assigned Metric Consensus Measure score were also rated 1-6 (strongly disagree

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to strongly agree) and were: availability 5.58, economics 5.68, quality/performance 5.86, service and design 5.50, and supplier measures 5.13. These scores also indicate a consensus, based on a Metric Consensus Measure score for each metric being greater than 5, had been reached among the buyers, suppliers, and end-users for the metrics and definitional dimensions for supplier selection for the MRO commodity roof control products. There was also little variability among the scores of the individual groups (SD Buyer = .49, SD Supplier = .65, and SD End-User = .42) or the average of all the groups (SD = .50).

Research Question RQ4

What weight of importance do buyers, suppliers, and end-users assign to the metrics?

In addition to providing a Metric Consensus Measure score for the purpose of identifying a consensus among the buyer, supplier, and end-user, participants also identified the weight of importance they would assign to each of the agreed upon metrics and definitions for supplier selection. The weight of importance was assigned to the metrics and definitional dimensions for both the capital equipment shearing machine and the MRO commodity roof control products.

The following is a list of the metrics and definitional dimensions with the combined average weight of importance as assigned by the buyers, suppliers, and end-users for the shearing machine. The metrics and definitional dimensions, along with the assigned weight of importance, are: availability 14%, economics 19%, quality/performance 26%, safety and service 18%, supplier measures 10% and technology 13%. The rank order for the metrics and definitional dimensions, as assigned by the participating groups, was: quality/performance, economics, safety and service, availability, technology, and supplier measures. There was also little variability

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among the scores of the individual groups (SD Buyer = .05, SD Supplier = .04, and SD End-User = .07) or the average of all the groups (SD = .06).

The weight of importance was also calculated for the MRO commodity roof control products. The following is a list of the metrics and definitional dimensions with the combined average weight of importance as assigned by the buyers, suppliers, and end-users for the MRO commodity roof control products. The metrics and definitional dimensions, along with the assigned weight of importance, were: availability 17%, economics 19%, quality/performance 28%, service and design 22%, and supplier measures 15%. The rank order for the metrics and definitional dimensions as assigned by the participating groups were: quality/performance, economics, safety and service, availability, and supplier measures. There was also little variability among the scores of the individual groups (SD Buyer = .05, SD Supplier = .56, and SD End-User = .09) or the average of all the groups (SD = .07).

One final point of interest was found in this study. Although the shearing machine and roof control products are two very different categories of items, the buyers, suppliers, and end-users also ranked them in the exact same order, with the exception of technology, which was not part of the roof control metrics and definitional dimensions. However, there was a slight difference in the actual weights assigned to the metrics and their underlying definitional dimensions.

Limitations in this Study

Even though this study provided a list of metrics, definitional dimensions, Metric Consensus Measure scores, and weight of importance as assigned by the buyers, suppliers, and end-users, there are limitations in the application of the results. The ability to generalize the results of this study is limited due to industry constraints and the low number of participants.

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There are also threats to the external validity of the study due to the limited number of people (Field & Hole, 2003) available with expertise on the two strategic sourcing programs used in the study. Further, the results are limited in application to the products reviewed (the shearer machine and roof control products) and the industry (mining) in which the study took place. Finally, there was also a low number of product suppliers in the industry, and it is possible that participant results could have been influenced by the culture and direction of their organizations.

Future Studies

Even though there are limitations to this study, there are areas for future research as well. This study was completed using a Delphi Method where the participant responses could not be identified among the individual participants. One area for study is to complete the same process using focus group study to identify whether the same results could be reached among the buyer, supplier, and end-user group of participants. Using the same group of participants could help to identify if further refinement of the metrics and their underlying definitional dimensions are possible.

An idea for another area for a future study came from one of the participants. It was suggested to complete the Delphi Method, and then in the final phase do a focus group to see if the results could be further refined. A study could be conducted at a company that implements the identified supplier selection metrics and definition process to determine if any value was gained as a result.

A third idea for further study comes from finding that a closer relationship among two groups (such as suppliers and end-users versus buyers, suppliers, and end-users) exists. A qualitative study to explore and explain this finding could help explicate it and might identify factors that influence such connections to form.

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A fourth study could be conducted across other business disciplines to identify if the same results are possible outside the mining industry; this would add to the body of research.

Another area to consider for study stems from the commonality found in the current study where both the metrics identified and their rank order of importance were identical for all commonly shared metrics. This area is particularly interesting due to the wide divergence in the two categories (capital equipment and commodity) of items that were used in the current research. It would be interesting to inquire as to whether there might be some general rank order of metrics for all, or specific groups of various categories of spend in the mining industry.

And finally, a sixth study is possible to identify if the Delphi method is possible through an automated technological process, through all phases, which may provide efficiencies in time utilization for members of the participant groups.

Concluding Comments

The Delphi Method used for this case study was very interesting and provided many insights to the participant company and its suppliers that would likely not have been identified if the study had not been done. The participants had 576 years of experience and hold various positions, from salesman to senior level executives. Without the breadth of participants' knowledge and experience, the results of this study could have produced metrics that remained broad and expansive, similar to that of metrics found in the literature, but would have had little impact for the company. However, it was the broad knowledge (both book and experience) base of the participants that added the depth (to the definitional dimensions) required at the company level and critical to the success of the study.

The body of knowledge for supply chain management was enhanced by answering the research questions. This study filled the need of rigorous qualitative research in the supply chain

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management field as was called for by Kotzab et al., (2005), as a means for viewing the field in a manner different from its traditionally quantitative perspective. This study indicated the need not only to review the metrics at the group level (buyer, supplier, and end-user), but also to share and discuss that information with each of the groups.

This research clearly identifies that the basic metrics are viewed as being the same (Table 4.1) among the buyers, suppliers, and end-users; however, the participants also identify a clear difference in how the metrics are defined. This finding is true for both the capital equipment item shearing machine and the MRO commodity roof control products.

This was a comprehensive and rigorous research study across several areas of the supply chain using the Delphi Method: supplier, buyer, and the end-user of the delivered equipment or commodity item used in the extraction of coal. This research filled a need in the supply chain management discipline by crossing different areas of the supply chain in one company and by also providing a qualitative study that more clearly explicates the intentions of these different areas with respect to the metric identification and definition; which is, according to Kotzab et al (2005), often done in the supply chain management field. The study also was conducted in a non-manufacturing setting, an area for which studies are underrepresented in the body of literature.

Moreover, based on the comments of participants in the buyer, supplier, and end-user roles, this study added value to the participant company and to its suppliers. For example, one buyer said:

> "I just think the value is if you can lay out metrics and lay out some processes, that makes that time element that we're crunched with at the end, it makes it so much easier. I come to you, and you

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> say, 'this is our process,' as superintendent someone has thought of a process; that's half the battle, I think. Then you just follow the process and if you follow the process it gets us to the end means and I think that's where we want to be. Half the time it's the process; we don't think of it. Yes, I think the value of the metrics is needed. It kind of sets the rules down and one thing about [the company] and rules – we kind of follow rules. Engineers are good at following rules and when you make them it's a lot easier – we just like to follow them. So I think there is a value in developing metrics between the products we're buying and the vendors we're dealing with."

The participants felt that this process should be completed on all major equipment, services, and MRO commodity products that are used in the mining process at the participant company. Further substantiation of the value of this process came from the multiple requests made from all levels of the participants for implementation of this process at the participant company. One of the buyers said, "I'm a big believer in what I call evidence-based management and in order to implement that you need evidence and you acquire evidence by keeping track of this and making sure you have your methods, so I can't see how you can possibly do this without maintaining these methods. I would like a copy of this study when it is completed and would like to see this process implemented at our company."

This study identified the need to define the supplier selection metrics not only on a macro level, but down to the level of equipment, product, or service utilization to provide the greatest value to the buyers, suppliers, and end-users. By engaging all participants within the organization

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in the Delphi Method, this study was able to identify the macro level metrics were very similar among the buyers, suppliers, and end-users. However, the definitions varied broadly when compared among the participant groups. If sourcing decisions are made based solely on metrics without clearly articulated definitions, the product, equipment, or service may not deliver the expected value to all stakeholders involved.

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APPENDICES

Appendix A: Definition of Terms

Buyer: The buyer in this study is defined as executive management and the supply chain management department. These two groups are involved in either the budgeting, strategic direction, alliance partnering, or tactical processing in the purchasing process.

Supplier: The supplier is defined as the bidding manufacturers, or distributors for the sourcing of commodities, services, and capital equipment to meet the requirements of the end-user.

End-user: The end-user for this study is defined as the mine managers and the individuals responsible for the application and use of the maintenance repair and operating supply (MRO) commodity, service, or capital equipment.

Metrics: A measure of a particular MRO commodity, capital equipment, or service required for production and utilized for decision support in strategic sourcing supplier selection; such as the price, quality, or deliver time of a particular service, commodity, or capital equipment.

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Appendix B: Sample Supplier Interview

Supplier One – Second Interview

D: Supplier One, what we'll start off with is the shearing machine metric and definitional dimension list and what I'd like to do is the first five questions of the metric interview list that you have there will be applicable to each individual metric and then questions 6, 7, 8 and 9 will be applicable to the list as an aggregate and how you answer those. The metrics are in no particular order; that's just the way they came out through the process. They're just numbered for the sake of identification. Each of the definitional dimensions is numbered, again for the sake of identification, no particular order, no particular reasoning for them We'll start with the metric Availability and the definitional dimensions. Would you agree with the metric nomenclature provided by the participants as listed and then just do your opinion, why or why not.

S1: In this definition, Availability has to do with – let's see – the definitional dimensions listed here, lead time for delivery must be spare parts availability, right – is that what you're talking about?

D: Yes, MRO – Maintenance, Repair and Operating Supplies – and the individuals that gave that spoke specifically about, obviously, the main components.

S1: Yes, critical components. Availability definitely has to be a metric in terms of this product. As far as Product Lead Time – you're talking about OEM lead time, is that right?

D: That's what the individual spoke about, right – from time of order to time of delivery of the shearing machine.

S1: I guess that would only come into play as far as the shortest lead time being an important definitional dimension if the buyer's organization was not good at placing orders far enough in advance. Certainly, MRO – main component availability has to play a big role because that contributes to your uptime. I guess product lead time is a definitional dimension, but I wouldn't rate it as a high definitional dimension in terms of its importance or weight within the metric of Availability. I think the onus rests on the buyer to know lead times of potential suppliers and to be able to place orders for the OEM delivery far enough in advance that OEM lead time isn't as big a contributor, but I agree that Availability is a metric, no doubt.

D: So any of the definitional dimensions listed – would you change, or would you add or take away?

S1: Availability – I have to be careful not to confuse this with the same definition of Performance because that's a different type of availability – that's uptime availability. In this

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definition of Availability, it's the availability of both the OEM of the original equipment and critical parts.

D: And componentry.

S1: Correct. I agree with that. I don't see any changes that need to be made.

D: Then we'll go to the second metric of Economics.

S1: Same question?

D: Same question – do you agree with the metric nomenclature as provided?

S1: Metric – I'm looking at the definitional dimensions that are all feeding that metric. We're not there yet, huh? You just want me to evaluate the metrics.

D: Yes, then we'll talk about the definitional dimensions.

S1: I agree – I agree with the metrics.

D: So you're okay with Economics as the nomenclature?

S1: Yes, that's a more broad based or broad brush term that encompasses a lot of the sub texts that we're going to discuss as far as definitional dimensions.

D: Right, so when you look now at the definitional dimensions 2A through 2Q, is there anything that you would change or is there anything you would add or take away?

S1: I think Cost of Ownership – there's going to be a fall-out of all of this, so I'm not sure Cost of Ownership plays in at this point. Cost of Ownership is going to be a result of all these metrics. In my view, it even has a higher definition than a metric, so I wouldn't put Cost of Ownership as a sub set of Economics because that's going to be a fall-out when all of these other definitional dimensions come into play.

D: Okay.

S1: You have labor cost here, is that labor and material or is that just labor?

D: Based on the participants' comments, I believe the intention was the material cost – the material cost of maintaining the machine. They didn't mention labor.

S1: So aren't H and I one and the same?

D: I is looking at what is the average, based on again, the participant – what is the average cost of those major components. Say, machine A versus machine B. You could say I is a sub-set of H.

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S1: Yes, that's what I'm saying.

D: So we'll put that down as a comment.

S1: In terms of performance guarantee when you look at a cost-per-ton agreement, let's say. Wouldn't those combine to form one – performance guarantee and tonnage guarantee?

D: Again, based on a participant's comments, he's looking at – not necessarily a tonnage guarantee, but an uptime guarantee, and then 2L was a sub-set of the same individual participant, and then a performance payment for that.

S1: Okay, so that's a risk reward?

D: Correct.

S1: I'm always thinking how this eventually factors in and has weight on and impact on Cost of Ownership because I think all of these are going to funnel there.

Inventory Cost - how does inventory cost play into this – your inventory cost - the owner's inventory cost?

D: The participant's comments there were, yes, what's the inventory carrying cost. What's the result of inventory cost, inventory carrying cost.

S1: The owner's inventory cost

D: Yes, not the supplier's cost.

S1: How does 2Q differ from 2I?

D: I would say – again, those are two different participants so I would say they're pretty close.

S1: Are we talking about the same thing, just with different nomenclature?

D: I don't know.

S1: In terms of maintenance costs, you have two components, right? You have a material component and you have a labor component. So, for instance, to compare the economics of a machine - while machine A and machine B may have equivalent time between failures for a particular component, but machine A only takes X minutes to replace that component and get the machine back into service versus machine B where you have X plus minutes. Therefore, you have a comparable advantage to machine A

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D: If you look in the third metric, that's one of the definitional dimensions given by the participants – ease of change. That's part of quality performance so major component cost and repair component cost are certainly similar. You say you would change one or eliminate one?

S1: Eliminate one.

D: Which one would you eliminate?

S1: If maintenance cost would encompass labor plus the major component cost – labor and material, then I think you can take out the repair component cost. I think they're one and the same.

D: Major component cost could also be, what is the cost of one versus another, which isn't a repair cost or traffic shield.

S1: Okay, so major component – you're talking a repair component versus a …

D: Versus a consumable product.

S1: Okay, then I'd rename that.

D: What would you rename it?

S1: Consumable Component Repair Cost.

D: Okay.

S1: In order to substantiate the difference between something that's considered to be a normal – like coal oil, lubricants and that sort of thing – does machine A require some special lubricant that's exorbitant in cost and that sort of thing. So yes, that would paint a differential between your normal cost and your rebuild cost for component cost.

Lease or buy – I guess that plays into the time value of money – lease or buy?

D: Yes, it's, again the participant's looking at – is the option there for lease or buy.

S1: Okay, and depending on the lease terms they may be attractive or they may not be, but it's a definitional dimension under Economics, I agree.

Under 2M – Rebuild Costs. I'd say that's going to include – that's your rebuild cost between usages?

D: Between panels.

S1: Which again is going to filter into the overall objective of minimum cost of ownership.

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D: Correct.

S1: I guess my biggest comment here is Cost of Ownership needs to come out of there – it's a higher level. It's not a definitional dimension under Economics, it's a higher level than even a metric here.

D: Okay.

S1: Standard wear item cost is repair component cost. In the terms we just talked about, in the terms of consumables – are we doubling up here? Similar – I think it's similar.

D: Okay.

S1: Maybe we need to combine those two.

D: Which two?

S1: 2M and 2Q. Standard Consumable Operating Cost or something of that nomenclature. Or Standard Consumable Cost or Operating Cost. Even for something like electricity – what if one machine is more efficient in its makeup that it operates the same horsepower with less electricity because it's designed better? I don't have any problem with that.

Lowest Present Value. So that's your lowest purchase price. Is that what that means?

D: I think that's lowest present value – based again on a participant's comments – is not only the acquisition cost, the exchange rate, looking at the lease, looking over the overall cost over a period of time and bringing it back to the lowest present value.

S1: Okay. I think that covers all the bases. Update cost – I think we've analyzed that to death.

D: So now we look at #3 – Quality/Performance. How are you with that nomenclature?

S1: I guess the question that comes to mind first is why were the metrics of Quality and Performance combined?

D: Quality and Performance based on the definitional dimension crossover, but again, I'm looking for your input.

S1: I know they go hand-in-hand. Let's see – which are performance-related and which ones are quality-related? Average tons a month – I'm trying to see where average tons come into play. I don't understand that definitional dimension. Demanded Usage - is that between rebuilds, or what?

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In terms of demanded usage, your total number of tons is defined, so you can have a rebuild in a panel whether that machine's ready for it or not. So at the end of the day that's not going to be the definitional dimension that gets the big play here, it's going to be the economics.

D: So you think 3A should be eliminated?

S1: Yes. Maybe a different way to put that would be the minimum number of tons that can be mined between rebuilds so that you know that machine is going to make it through a planned entire panel without a rebuild.

D: So change to ..

S1: Tons between Rebuild.

D: Okay.

S1: I think you need to look at that and look at the demand that you're going to place on that machine and make sure that machine can make it through a panel without a rebuild. That's the way I'd define it.

D: Okay.

S1: Downtime should be as a follow-up. Downtime is going to be determined when you define the time between failures and the time to repair those failures. Did we pick that up or does that have to stay? You have machine uptime and downtime. I think one of those needs to go. 3M and 3E – to me they mean one and the same, you're just saying them in different ways. Right?

D: So which one do you think should go?

S1: Doesn't matter, pick one. Downtime is the typical – this is when you get into shift availability.

D: So if we're looking at Shift Availability, you want to eliminate downtime? I mean the definitional dimension, obviously.

S1: Yes. Don't we want to use the percent of availability here?

D: Then you want to change machine uptime percentage?

S1: I think machine availability is the more proper term. Whether you eliminate both machine uptime and downtime with one definitional dimension, machine availability – that's what I would do.

D: Okay.

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S1: Machine availability encompasses those two things – machine uptime and machine downtime.

Ease of Use – that's going to be a tough one to measure. Doesn't that match up well with component ease of change or operating ease of change?

D: The participant again in their discussion spoke about the capacity for an individual to operate the machine.

S1: So this is more operator user friendly?

D: Correct.

S1: Well, I'd agree with that.

Fit for Use? What does that mean? Fit for Purpose?

D: Again, based on a participant discussion, Fit for Purpose was – is the machine applicable to the seam of coal that it's mining in; does it meet that requirement.

S1: Don't you get that by defining the requirements in 3I and 3K which are Tractive Effort and Horsepower, whether it's in concert with the requirements for mining that coal seam?

D: Say that again.

S1: 3I and 3K. Those are your determinants, if you will, to evaluate whether that machine is fit for purpose.

D: Okay.

S1: I'm trying to condense some of this because I think we have too many definitional dimensions here that are kind of duplicative.

Cutting Speed you have. So all of these performance parameters are definitional dimensions/definitional dimensions – cutting speed, tractive effort, horsepower, range of haulage arms - I think all three of those items are going to determine whether that machine is fit for use, so do we need to have that term Fit for Use as a definitional dimension? I think you as a user would define whether a machine is fit for use by evaluating the cutting speed, capability, draw bar pull and ranging arm horsepower

D: All right.

S1: Machine cutting capacity – that's a fall-out, too. I think that falls out. Once you've defined cutting speed you've defined cutting capacity. So that's redundant.

D: So 3L can be eliminated.

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S1: I think so.

D: Okay.

S1: Speed capacity, but also web depth. You could have a machine that can have the cutting speeds but one could be that speed with a 36" web and the other one could do it with a 42" web, then production capacity comes into play. I'm trying to boil some of this down because some of these could be combined into one definitional dimension. I think as a buyer you want to simplify these measures so you can be sure you evaluate that metric properly. If you slice this metric into too many pieces then it starts to get polluted. I would prefer to see some of these condensed if possible; things like the cutting capacity and some of the performance definitional dimensions are design definitional dimensions, if you will. If I were going to eliminate one in the interest of condensing this list, I'd probably eliminate cutting speed and leave in cutting capacity.

D: So eliminate 3D?

S1: Yes, and keep machine cutting capacity because that gives you both sub sets of what you're looking for, which is speed along with productivity. As I said, if you have a machine cutting 24" web at 100 ft. a minute and another one cutting at 36" web at 100 ft. a minute, the better value is the one with the bigger web. Your tons-per-hour are going to be what you're looking for there.

S1: Unplanned outages. That one definitional dimension there may be difficult to measure - level of automation – do we have that anywhere? Technology?

D: Yes, it speaks significantly about…

S1: All right, so we'll cover that under a different definitional dimension. Quality Assurance Program. - the problem I have with this is, everybody and his mother is ISO 9000 Certified so how are you as a buyer going to differentiate between Vendor A and Vendor B if both are ISO 9000 Certified other than, "are you ISO 9000 Certified?"

D: I think that becomes inherent on the end-user and the maintenance operators to define.

S1: All you're asking here in terms of definitional dimension is the manufacturer ISO certified with some QA program in place.

D: That's right – what is your QA program and define that. That would end up being, define your QA program, and then an end-user/maintenance would have to determine if there is any value between suppliers A, B or C's QA program.

S1: In my view, the end-user's measurement metric of whether a vendor is a quality vendor comes back to downtime – back to time between failures. If you have a quality product, assuming the engineering design is solid, then the only other variable in terms of how that

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machine performs is whether it's built in a quality fashion, built to the engineering standards to which it was designed.

D: If you listen to the participants in the conversations, quality assurance is – and they overlap maybe into Safety and Service and Supplier Measures – how does a supplier look at and define component failure as far as improvement in the future.

S1: Continuous Improvement Process.

D: Yes, which is in there under another…

S1: That's what I'm saying – are we getting an overlap there?

D: It could be considered an overlap.

S1: That's what my original intent was here, why would you decide to combine Performance and Quality because I think that they are two different metrics.

D: Okay, so in your view, they should be segregated.

S1: Yes, there's Performance on one hand which encompasses the design and engineering; what the capabilities of the machine are from an engineering standpoint, and Quality encompasses how well it's built in conformance to the design standard it was intended. Beyond that, as you just said, is what quality programs are there in place by the vendor to monitor in-progress use to improve the product as you go forward. I would split that metric and dice up the definitional dimensions that go along with each of those.

D: Okay

S1: That's just my view.

D: That's what I'm looking for.

S1: I think you dilute the importance of those when you combine them

D: Okay.

S1: Other than that – warranty – why aren't warranties part of Economics? I think warranties should be Economics because all warranty-associated expenses are just that; they're costs, which in my view play into Economics. Conversely, you could say that the warranty that the vendor gives you – is there confidence in the design performance standard that they're purporting?

D: Most of the participants that spoke about warranties spoke about exactly that, confidence level of the quality/performance.

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S1: I can see it from that perspective. I could go either way; I'd like to see them in Economics, but as long as the warranty aspects are in one of these metrics, I'm okay with it.

D: Okay.

S1: Tonnage – again that gets into the – again, this is all confidence. What's warranty parameter? I don't understand that one.

D: The participant that talked about that – I'm trying to recall the conversation – warranty parameters of – it almost was – talked about componentry and how they fit. I don't remember a whole lot of that conversation, but it would certainly be similar to the warranty claim in process.

S1: The claim process I think goes under Supplier Measures because looking ahead here a little bit, Supplier Measures is the relationship between the user and the supplier, is it not?

D: Yes.

S1: So I think claim resolution process should go under Supplier Measures.

D: So you would eliminate 3S.

S1: Yes. Well, I just don't know what 3S really means – whether it needs to be eliminated – I don't understand, I guess, the definition of Warranty Parameter.

D: Okay.

S1: I think you can almost correlate 3A and 3T. We talked about average tons mined which we eliminated. We said minimum tons between rebuilds.

D: We changed that to tons between rebuilds.

S1: Right.

D: Okay, I understand what you're saying.

S1: Those are one and the same so if the seller is going to warrant minimum tonnage between rebuilds, that would be 3T. It's just confidence in his claim that that machine will make it X number of tons between rebuilds and what are the consequences if it doesn't. That's another question.

We talked about Automation. That has to be somewhere else in terms of Technology. When I start looking at Metric #6, Technology, I'm wondering why that's broken out as a separate metric and not included under Performance. Let me think about that. Don't all of those definitions contribute to performance – not electronic parts books, but all of those definitional dimensions in terms of technological capabilities have a direct impact on performance so why aren't they the same? That would be my question. I guess maybe the answer there is you don't

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want to have too many definitions under one metric so that we don't get diluted again. Maybe I just answered my own question. Right?

D: Yes

S1: All right, I think we're done with metric 3.

D: Okay, #4, Safety and Service.

S1: Body positioning. Does that mean…

D: That participant was speaking specifically of the operator.

S1: Okay – whether he's able to operate the machine from a safe location.

D: Correct.

S1: To answer that question, guess where you're going to go – you're going to go to Technology because it becomes remote operation. If you want that guy in a safe location, you're going to have some form of remote control to allow him to be able to operate that safely, but it is a safety definitional dimension – I understand that. Safety and Service definitional dimension.

D: Based on the participant, it is.

S1: Continuous Improvement Process. I think that's Quality. It comes out of there and goes into Quality. Split Quality and Performance into two different metrics; the CIP goes into that and out of here. The same as design review; that doesn't belong in Safety and Service.

Dust rating – what does that mean – is that dust make?

D: Yes.

S1: How do you measure that?

D: I can't tell you – I know it is measured on the face, our Safety measures it, but I can't tell you. In many cases it's more a product of the drum and bits.

S1: That's my point. If we're going to make that part of the machine metrics, somewhere in here there has to be drum design or are we just going to use the dust?

D: Drum design – where would you add that?

S1: Well, the drum design is going to have a definite impact on machine cutting capacity. It might be a great drum for cutting, but it might be a lousy drum for dust making. I guess what we're doing there is we're comparing - the drum design is already inherent then. We're saying with this drum design this machine can cut X tons per hour, at a certain speed, certain web depth.

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D: What the participant is looking at is what effect is that going to have on dust make, which obviously is a regulational issue?

S1: That's going to be a tough one to measure. For a supplier to give you – I mean, they can quote you dust make, but …

D: They would have to elaborate – the drum maker and the bits and they could answer the question based on this drum design based on this bit and this bit block.

S1: I'm just saying that's going to be tough. That's measurable after the fact, but in the buying process I'm not so sure you're going to get somebody to commit to a dust make, milligrams per lead or whatever. That's just a comment.

Engineering resources – doesn't that go to Supplier Measures?

D: Again, more than one participant felt that was a service level definitional dimension.

S1: Installation – that's flat out service, isn't it?

D: Yes.

S1: Why do you have Problem Analysis and Engineering Resources? Aren't they one and the same? Why do you need both? That's what you need Engineering Resources for, isn't it?

D: So you would eliminate 4?

S1: One or the other.

D: L?

S1: Yes, I'd say. You have Engineering Resources in there as a definitional dimension and I don't think you need Problem Analysis, especially if you have response time because response time should be applicable to engineering resource response as well as service resource response.

D: Okay.

S1: Personnel Qualification – I agree with that; just sending warm bodies doesn't get it.

D: No.

S1: Lubricant management – that's part of your service. Okay. Service Availability – are we duplicating things when we say response time or are they two different things?

D: I think they're two different things. If you're looking at similarities, that's probably more similar to 4J.

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S1:	Yes. Here again, in the interest of trying to condense some of these definitional dimensions…

D:	Sure, you could combine Service Availability and combine…

S1:	Put Service Availability online, off site, on site – combine those into one.

Safety Characteristics – now that's a broad brush term.

D:	Yes.

S1:	That's too broad.

D:	Maybe Safety Training. I think what the participant talked about was stock switches, almost a methane monitor stock. Safety controls, maybe.

S1:	Okay. I'm not saying it doesn't need to be there; maybe it needs to be a little better defined, what you mean by safety characteristics, and I'm sure the user has definite ideas on what characteristics they want to see from a safety standpoint on the machine. That's more of a check list to make sure that the supplier complies with all those requirements

D:	In essence, that's what the metric and the definitional dimension end up being – an adequate measuring stick.

S1:	Okay. Joint Performance Ownership – this is the proverbial "skin in the game."

D:	Yes.

S1:	How does that fall under Service? It certainly isn't Safety.

D:	No.

S1:	How does that definitional dimension apply to Service? Isn't that more of an Economic definitional dimension or Supplier Measures definitional dimension rather than Service? I think that needs to be moved. I don't want to eliminate the definitional dimension; I think the definitional dimension needs to go somewhere else.

D:	Where would you put it?

S1:	I'd put it in the Supplier Measures.

D:	Okay.

S1:	Again, that's almost one – you look back at the Economics metric and you have performance payment, so those two are almost – they're similar – between Joint Performance

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Ownership and Performance Payment. They're similar concepts, so as I say, you can go either place; you can go to Economics or you can go to Supplier Measures.

D: As a Supplier Measure it would be, "are you willing to put your "skin in the game?'

S1: Yes. Then again, wouldn't that be evident if they are agreeable to a performance payment?

D: If they were agreeable to a performance guarantee. Performance guarantee and performance payment are in itself a "skin in the game" for the end-user.

S1: Right. So are we duplicating something there?

D: So would you eliminate it then?

S1: Yes, I'd take it out because we already have it covered under Economics. All right, I think we've covered the Safety and Service thing.

D: Okay.

S1: Supplier Measures.

D: #5

S1: I'm trying to get a grip on what we mean by Supplier Measures. This goes more along the line of a user-supplier partnership. Is that what we're defining here?

D: Correct.

S1: And what definitional dimensions are used to define that partnership.

D: And the strength and capacity of the supplier.

S1: Yes. Alliance Investments – does that mean the upfront investment by the supplier in the partnership?

D: Again, based on a participant, that gets back to the "skin in the game." What are they bringing to the table for an alliance? You can almost look at the rest of them – are they bringing technology support, are they bringing service support, are they bringing safety support?

S1: That's what I mean, aren't we picking that up inherently with all these other definitional dimensions?

D: You could say you are.

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S1:	Because the length of the alliance, the spend – all that represents an investment in the alliance so I don't see why Alliance Investment needs to be there because you're going to pick that up with the other definitional dimensions. You can't eliminate these other ones because they represent part of the investment.

Fleet Size - does that mean their population in service or like kind equipment?

D:	Correct.

S1:	Financial strength. Does financial strength mean volume?

D:	Financial strength means is the company financially sound; you know, run a Dun & Bradstreet on it.

S1:	Yes, you don't want to go to Joe's Shearing machine Shop down in Farmington.

D:	Yes, you don't want to buy six $3M shearing machines and the find out that they have them financed for thirty years.

S1:	Okay. Historical Performance – does that mean experience? Probably.

D:	Yes, based again upon a participant conversation.

S1:	Is this machine a brand new guinea pig or is this a proven product.

D:	Right.

S1:	Fleet Size and Historical Performance are similar, but they deserve their separation I guess.

Life Cycle Management – Isn't that more of an economical thing?

D:	That, again, the participant talked about, "do you have a supplier willing to participate from "birth to death" and the management of that cost management of that.

S1:	That's what I'm saying – cost management – doesn't that get into the economics?

D:	It could, yes.

S1:	Life Cycle Management needs to stay in – the question is, where would it best fit in as a definitional dimension?

D:	Again, based on a participant conversation, that is the availability of it and how they do it as tied to a supplier versus an economic cost. If the supplier doesn't do it, it doesn't cost you anything, but …

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S1: All right, got it. Product Support – don't we pick that up as a definitional dimension under Service? We have engineering resources, we have the service resources; so if we have them under the metric of Safety and Service, I don't see why we need to repeat it here.

D: So eliminate 5J.

S1: R&D spend – I guess you can measure that; how high of an import you can give that is another question.

D: Yes, it just becomes a definitional dimension of the supplier's capabilities and almost a confidence level of are they in this industry for the long term.

S1: Yes, that will go hand-in-hand with financial strength. If you have a financially strong company you're going to see a significant R&D spend so they'll probably end up paralleling each other very closely.

D: Well, what it may do for you is if you have a company that's non-public and a non-public company provides you their R&D and you see that R&D shrinking you know that they're…

S1: Or, if you have a Chinese company that's purely a copier, you have no R&D, you just have reverse engineering.

D: Right.

S1: Rebuild Warranty – that goes in with Product Life Cycle Management. Won't that end up going back to Economics or Performance? I think all your warranty items need to be grouped under one metric, whether it is original or rebuilt. Again, all of this is going to funnel back to Cost of Ownership anyway – that's going to be the prize metric if you want to call it that.

D: That almost becomes post validation – post purchase validation.

S1: System Integration – what do we mean by that?

D: That is clearly, "do your systems talk – do I have to fax you a purchase order" …

S1: Okay, this is business – this is business-systems integration.

D: Yes.

S1: So that's basically with the eye towards minimization of transactions cost. Is this a different enough definitional dimension that they need their own line item – transaction cost and system integration?

D: The only difference would be if there's not system integration with two different suppliers would you still look at the transaction cost or would it be the same? If it's not system-

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to-system, what is it and what is the cost to do that? What does it cost you to do business with them?

S1: Right. So if you leave transaction cost in there – I understand what you're trying to get at here, we want to streamline the business process.

D: Yes, it's probably more related – the system integration to procure-to-pay process under 5A

S1: We might be duplicating with just different terminology here is what I'm saying. So which one is the best overall definitional dimension that encompasses all of these ideals because just because you have a system integration doesn't mean it's the lowest cost of transaction, right?

D: That's right.

S1: What exactly do you mean by procure-to-pay process?

D: That participant spoke about – again, that's the system - is it an electronic, touchless process or is it a paper trail process.

J: We can leave them in to give it more clarity, but I think we're duplicating some.

D: Which one would you eliminate?

D: One or the other – system integration or procure-to-pay. One of those should go because I think they're one and the same.

D: Procure-to-pay is quite clear; system integration is fuzzy.

S1: Yes, it's wishy-washy. Right, so I'd take system integration out. As long as you leave transaction cost and the procure-to-pay, I think you'll get the value of system integration, what that translates into.

Product Enhancements – doesn't that go along with R&D spend? No, they're two different things – you could spend a lot of money on R&D, but if you don't get any results, you don't get any product enhancements. Aren't you going to get that under Technology?

D: Well, the participant talked about – and you could argue that – what has occurred with that product from inception till now. Is it the same; does it have some different enhancements to make it a better product; has anything been done with it; am I buying the last one?

S1: Am I buying a 67 Packard and I'm going to be owning it till it dies?

D: Yes.

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S1:	I'm wondering if there's a better definitional dimension that would go under. I think Performance is what you want to look at because here you're trying to measure the ability of the company to provide enhancements. Another way to look at it – is the machine designed in such a way that it will allow enhancements to be added as they become available, or am I buying a template that isn't expandable. In other words, I have a certain body and is this body designed to accept higher horsepower arms later on if I want to go that way or because of the frame design is it limited on capability. Maybe there needs to be a differentiation. What you're trying to do here is measure the company's intention to improve its products over time. Maybe we missed one back in Performance. I'm not sure whether we did or not. Let's see – head room, upgrade ability; these are probably nebulous terms, but they may be hard to measure – design for future enhancements - I would go back to Performance and put some terminology in for design for future performance enhancements.

D:	So add into 3.

S1:	Design for future enhancements. In other words, you're not stuck with a stagnant design, that it has a platform that will allow performance enhancements as those designs become available.

D:	Then you would eliminate 5P.

S1:	Yes.

D:	Okay.

S1:	Manufacturing capacity – again, that's a measure of the company's wherewithal and ability to adapt to market fluctuation.

D:	Correct.

S1:	But you have to be careful there in how you value that because over-capacity costs money; under-utilization costs money, so just having 20,000 or 200,000 square feet of manufacturing capability doesn't necessarily translate into a high rating.

D:	You have to understand the market, market conditions, expected market conditions, and that might have no weight whatsoever in the end result or if you know for a fact that 80% of the shearing machines in the US market are at the end or near the end of their life cycle are you going to get stuck in a quandary because now they're going to sell.

S1:	Okay. I'm just highlighting caution in the terms of the evaluation of that particular definitional dimension.

D:	And that should be noted in the weight of importance.

S1:	Yes, and that's going to be a fallout. I think you're looking at manufacturing capacity as purely the ability of the supplier to meet your needs.

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D: Correct.

S1: Your needs as well as the market's needs.

D: That's right.

S1: And if they're over capacity, that's going to translate to Economics. Or under capacity.

D: Diesel equipment availability today is very difficult and you're held hostage to that market because there aren't many choices.

S1: Right. Okay, metric 6 - Onboard Vibration. That's comes under Onboard Health Monitoring I think. Technical Capability; I think that's a broad brush, too.

D: So you would eliminate that one – 6L?

S1: I don't see where Information Flow is necessary; if you have all these other things, I assume it's flowing. I'd eliminate information flow. As long as you have diagnostics and even electronic information availability. I think that's inherent when you say Onboard Health Monitoring and Diagnostic Capability. As long as you have those two, I don't see why you need 6B and 6C.

Onboard Vibration Analysis – that's probably under Health Monitoring and you're going to get that anyway. You can keep it, but Health Monitoring – you're probably going to need sub sets of that. What all health parameters are included in the health monitoring system – the more the better as long as they're reliable. What you don't want to do is have a system that is so complex that it thinks it's sick and it shuts down and it's really not sick because your onboard health monitoring system went haywire. It's reading a temperature of 104 and you really have 98.6. So somewhere reliability has to be a factor here – reliability of your health monitoring system.

D: What nomenclature would you give to that definitional dimension?

S1: Automation Reliability; let's call it that. That covers all aspects.

Continuous Technological Improvement Process – we already covered that; why does that have to go in here? That doesn't belong here.

Electronic Parts Books – I think that's more of a business thing.

D: Where would you put that – under Supplier Measures?

S1: Where was that?

D: That's 5.

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S1: Yes, that goes along with what we talked about – transaction costs, procure-to-pay; if you have electronic parts books – so I'd move that up there.

D: Sure.

S1: Safety Support. Didn't we cover that already over here under Safety?

D: Yes – the participant there specifically talked about the technology aspect of safety support – what it's there for in other words – I'm not sure how to verbalize it.

S1: I'm just having difficulty understanding what we mean by Safety Support if it's not already included under Safety.

D: So you think we should move that one or that it's already encompassed?

S1: I think it's already encompassed under Safety.

D: Okay.

S1: Because what you're after here - in terms of technology, I think you're looking at the ability of the machine to operate in an automated environment.

D: Correct.

S1: As little human intervention as possible.

D: Yes, procure-to-pay is electronic without touching it and technology is …

S1: Operating without touching it and what you're after here is that some day that guy is – I think the next step is that the operator is going to be sitting at the head gate. I think that's going to be the first step, and that machine is going to be going down the face and he's going to be watching a computer screen seeing what that machine is doing and knowing just as much as if he were standing next to it.

Now, did we go through 5 – did we answer all of that?

D: Yes; 1 through 6. Now we go to questions 6, 7, 8 and 9 which encompass the aggregates of the metric and definitional dimensions. 6 is, do you believe the set of metrics and definitional dimensions provided by the participants is appropriate for supplier selection.

S1: Yes, I think it covers the whole spectrum.

D: Then 7 is, do the definitional dimensions define the metrics as provided by the participants.

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S1: Yes, I think we just went through that pretty much in detail. I made my comments so the ones I didn't think applied, I think we took out.

D: Yes, so other than those, they do.

S1: Right.

D: And then the next one is, what weight of importance would you assign to each metric as is, equaling 100% - prior to changes that you made – so starting with 1. It doesn't matter – start with whichever one you want and give a weight or importance.

S1: Let me sort this out. Economics should be 25%; Quality & Performance should be 25%; Availability 15%; Safety and Service 15%; and 10% each for the Supplier Measures and Technology. Did I catch them all?

D: Yes. Now the last question is, what Likert format score would you assign to each metric, as is, on a scale of one-to-six; we eliminated Neutral.

S1: So what I'm responding to here is whether these definitional dimensions adequately define Availabilty?

D: No.

S1: Okay, explain this to me.

D: The metric and definitional dimensions together – are they adequate in supplier selection to what agreement extent from Strongly Disagree, obviously, to Strongly Agree - as is, right this minute, before any changes. The next one will be with the changes.

S1: Okay. Let me go back and look. My agreement level would be parallel with how many changes I made, right?

D: I would think.

S1: Lead time.

S1: The one change you made in there was critical components instead of main components. That was the only change you requested for definitional dimensions.

S1: Yes, I would agree. Give it a 5.

D: #2 you made numerous changes. TCO you would take out.

S1: Yes, take it out.

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D: 2A is the sub set of maintenance cost. 2I you were saying to change to component cost, and 2N and 2Q kind of fit a standard operating cost.

S1: I would moderately agree, so that's a 4.

D: Performance and Quality should be segregated, you said.

S1: Yes, I did.

D: And you made numerous changes, so what level?

S1: I'd put 3; it just needs reworked. The biggest thing, we need to split Quality and Performance. That's where I disagree. It's not that I disagree with it, it's just the makeup of that metric I think needs to be split –not necessarily the definitional dimensions, but they need to be split into the Quality definitional dimensions and the Performance definitional dimensions.

D: Okay. #4 you would say goes – 4C went with Quality. 4D moved to Quality, 4L eliminate. 4P and J combined.

S1: Make that a 4.

D: Okay. And 5 you had four changes.

S1: Five changes.

D: Some just moved, some eliminated – you had four eliminates.

S1: I don't necessarily disagree, but I guess you could define that as moderately agree, not totally. Right?

D: Okay – moderately or we could say somewhat. #6.

S1: Technology. Again, "moderately agree" because we made significant changes.

D: We made several changes.

S1: That's another 4.

D: Okay. Thank you.

S1: You're welcome!

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Appendix C: Sample Buyer First Interview

Buyer Interview

D: Buyer, if you would please provide me with a brief background of your work experience including you current responsibilities, length of time you've been with your current employer and in the mining industry.

B1: I'm Buyer. I've been with the participant company for six years, the last as Chief Operating Officer of coal. Prior to that I was Sr. Vice President for coal operations and another time Sr. Vice President for Administration, Planning, Purchasing (Supply Chain Management), Land and R&D. I started with participant company as the vice president of operations support in charge of engineering environmental committee. Prior to that I worked with a couple competitor companies, the latest being Foundation, which was RAG American Coal at that time and prior to that, Cypress Amax . I spent a couple of years with that company and then it changed hands and merged during that tenure I had with them. I had a twelve year stint with Pacific Corp, Utah Power, Pacific Power and was in charge of several mining operations there and also some non-captive power plants. Before that I worked for US Steel and Kaiser Steel, so I have twenty-eight years of mining experience and fuel resource experience both in underground, surface and processing. That's pretty much my experience. As far as the job responsibilities now I have all the coal mining operations for all the regions under CONSOL and joint venture partnerships from an operating standpoint and service standpoint,

D: That's good; that gives me a good background. The first question for the study is, what metrics would you use for strategic sourcing supplier selection for the purpose of capital equipment, and for this study we've narrowed it down to a shearing machine. It's really a four-part question: why those metrics and how would you define each of those metrics, what definitional dimensions would you assign to the metrics and what weight of importance or what rank order to the metrics would you put them in?

B1: The shearing machines are the life blood and heart and soul of longwall systems and they happen to be the machines with the most moving parts. Due to that we're using machines with the most potential for breakdown or failure to the system, like mechanical or hydraulic systems. With our tracking systems that we have with our industrial engineering group, they happen to have the highest amount of downtime – when we try to track through – they're the leader in downtime. That's relative to all shearing machines, but as far as selecting the metrics to evaluate one machine – either one model or one manufacturer compared to another, it's going to have to be he the durability of the machine and the anticipated uptime. In some cases it's the proven track record of the machine. So, from the standpoint of looking at your machine – because it's something different each model year or from model to model, and every time there's a change there's usually some type of system that gets tested because of the mining environment, normally one of the toughest mining environments for the machine to work in. To give you an example of a machine that may be a superior machine, one year we had a seal design and in this case a caterpillar planetary type seal on the ranging arm hub itself was changed and the material used was changed and it caused some problems – failure, significant downtime. A small engineering

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change like that sometimes has a domino effect on the machine, both on the uptime and the downtime of the machine. So, from a metric standpoint, looking model-to-model since there are very few machines to select from from a manufacturer's standpoint, it comes down to the quality control and engineering that's put into each design. change or even the initial design of the machine. Shearing machines are just a natural progression of the model prior to the latest model - and I'll talk from the manufacturers' standpoint first – manufacturers are of course looking for the most efficient design; they're looking to optimize through finite element modeling or mechanical engineering modeling to optimize the materials that are used; they're trying to make the machine more efficient
if possible and of course there's an OEM aftermarket parts business that gets attached to the machine. Since they're such a specialized unit you would anticipate that the manufacturers would want to keep the machine as user friendly and problem-free as possible. Unfortunately that's not always the case because applied design from the engineer's perspective for the manufacturer may not be the tried and true environmental design that's necessary underground. I think we've seen a lot of success as both the user and the buyer when the user of the machine comes up with some design ideas that are gleaned either by trial and error or tried and true application they come up with ideas that can be conveyed and communicated to the actual design team of the manufacturer. Now that's a little bit of a rarity for shearing machines maybe, but not so much for other pieces of longwall equipment. Something that might help both parties is in an alliance agreement where you can get both engineering groups together, especially where you go through a lot of volume of these machines and probably being one of the biggest buyer of these machines we can get some of our engineering expertise to help them with the design. So, one of the metrics has to be engineering of the machine and how the communication is relayed back and forth from the manufacturer to the buyer.

D: That one metric that I put there, and again please don't let me put words in your mouth, is durability and quality and then the definitional dimensions under that is engineering capacity and the research and development of the machine. The user friendly, we'd have to define that maybe a little clearer, but also then a definitional dimension is communication of design between user and design engineer.

B1: And to speak from the standpoint of the durability of the machine and also the use of end-user, it's a matter or whether or not you can solve the problem as quickly as possible if there is going to be a problem. So the problems of the past weigh heavily on the selection in the future and when you have a machine that's put into an environment that not readily accessible and you can get actually in an area that's unstable from the standpoint of a safety concern, then what you really try to select from a buyer standpoint is a machine that has again a lot of availability, a lot of uptime, but also that can be repaired quickly and diagnosed quickly from a problem standpoint. As an example of that type of problem, electrical systems are very important, especially as the systems become computerized with the new veritable frequency technology. That change in design and electrical control system has caused problems. Again they need to be field-tested somewhat to determine what the problems are, but to field test the machine you have to basically put it into the war zone basically. So it's very important, again from a buyer's standpoint that the machine has to be quick, has to be efficient, the troubleshooting systems have to be very clear to the end-user. These are all things that the buyer considers in a machine

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because they are somewhat of a physical demanding issue – usually people don't forget – the selector or the operator doesn't forget or the operator doesn't forget what the problems are.

D: Under the metric availability the definitional dimensions that I'm hearing is uptime – machine uptime and repair time and mechanical systems, electrical systems and hydraulic systems. We spoke about these systems earlier and then troubleshooting technology, what's the diagnostic …

B1: Diagnostic capability. It's just like taking your car to the shop It seems these machines are becoming very similar to an automobile where everything has several computers and there's a diagnostic system and several codes that are used to determine where the problem is and that's part of that process. Shearing machines have to be more durable than automobiles.

D: Yes.

B1: From an economic standpoint, then, the application and the availability and success of the machine go back into the economics of the machine, so if a manufacturer states that they expect 90% uptime, which would be a high number for our actual experience, 90% uptime for a certain machine, and it doesn't appear that he can make that uptime based on the design and the specifications, then the buyer is going to derate the value of the machine due to what's actually experienced. If it's a 5% drop, it's a 5% drop, so the selection of the machine – say there's only one machine available, what you're willing to pay for the machine may ultimately be determined by how much utilization you have on the machine because of uptime. In a sense, if that machine's down. the manufacturing facility is down – we manufacture coal with that machine – the entire power plant is down, so that's a very important aspect of the coal mining business. So from an economic standpoint we would definitely look at value in change in the machine or higher horsepower improvement based on what production time you have or what utilization time you have coupled with the anticipated availability. Again, every time there's a design change there has to be some factor incorporated into that calculation that will determine just how much time you're going to lose just because of the bugs in the system.

D: Under economics – the one definitional dimension, and I want to make sure I heard this, is uptime rating or de-rating actually built into the quote itself. And with the rating or de-rating it may end up being actually a post purchase if they don't hit the criteria that they agreed to.

B1: Performance guarantee.

D: Performance guarantee.

B1: If the manufacturer is willing to actually put their money where their mouth is and give us a guarantee of the performance. Now, performance guarantees are all fine and dandy on paper, but the actual time lost or production lost or units lost are really debatable and are hard to quantify at times, but the magnitude of those production units lost are very high. And for a machine that relatively is not a fraction of the total expense of the longwall system you are depending heavily on that machine and if there's a way to make it 95% available – no matter if

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you added 20 or 30% of the cost the economics would still be there as long as you could count on that uptime and that guarantee.

D: And one way to do that is the definitional dimension of a performance guarantee to see if a supplier is willing to do exactly that – their confidence level and what they're saying as far as uptime rating or de-rating.

B1: I think the other part that we can't really to miss is the safety aspects of the machine, too. How the operators are required to operate that machine from a visibility standpoint, body positioning standpoint, body positioning being from both a physical standpoint and also from a respirable dust standpoint, the ease of the machine for the mechanics to work on, the understandability of the electrical systems, the hydraulic systems and of course the procedures the manufacturer has developed to maintain the machine are also very important. You can't lose sight of the safety aspects of the machine. Comparable machines could – repair on one machine may take four or five times longer than another manufacturer's machine. So both from an economic standpoint and a safety standpoint when the machine goes down you're exposing your people for a longer period of time which, again, the ease of maintenance and ease of component change-out are very important also – and accessibility of key components that are vital organs of the machine are very important, too. We found that in my career. Shearing machines have been developed over time and I started with 1LS machine, a Joy machine, and worked to a 7 and 8LS machine. But there have been a lot of design improvements and a definitely a lot of safety improvements over that time period.

D: So safety characteristics, repair time and key component access.

B1: Key components that can be safely accessed and the procedures to change a component that are very well spelled out from the standpoint of body positioning so that no one is placed in an area where they can be in a pinch point or somewhere that they can be harmed. I think part of that maintenance aspect and part of the uptime is to have - one of the other metrics to have one of the manufacturer's servicemen available.

D: So service …

B1: Service and having someone on call to actually troubleshoot some of the potential machine problems that's readily available especially for a new version of a machine or a new machine because even new machines that have proven technology can still have some startup problems. Over 50% of our machines have startup glitches right now.

D: So technician availability and two other definitional dimensions were onsite and offsite - can you get them there or make a phone call for help.

B1: And it's even more important when you don't have a big staff and we're blessed with a lot of experts in-house, but if you have a small staff like a lot of companies you're in trouble.

D: Any other definitional dimensions you would assign to service?

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B1: The computer system itself for gathering data for the machine – again, this is part of the accessibility of the machine for data – the diagnostic part. The system that allows trending and troubleshooting in order to determine the electrical load on the motors and some of the other aspects of the machine that are valuable both currently and in the future for future design consideration. Our machines use a set of production rate that pushes those limits – electrical limits, mechanical limits to the point where it is critical to be tracking the average on the motors and being able to troubleshoot oil samples and that sort of thing if it gets to that point, to determine if there's a problem prior to a failure. Once again it's very important to get the machine positioned for repair, out of harm's way in a more stable area on the longwall face.

D: It's almost a preventative maintenance type information.

B1: Yes, and a maintenance indicator, positioning the machine in the most successful areas.

D: So far I have quality and durability, availability, economics, safety, and service. They are the five metrics. definitional dimensions – just to review – were engineering availability under quality, research and development of the machine, user friendly, communication on design of the machine between the user and design engineer. Under availability we had uptime, repair time of key components on mechanical systems, electrical systems, hydraulics systems and diagnostic system available for troubleshooting. Under economics we looked at rating or de-rating and a performance guarantee based on that uptime or rating or de-rating. Under safety we talked about machine positioning for operation, dust rating, ease of repair for mechanics such as repair time of key components to lessen exposure, safety characteristics such as key component access and solid repair procedures to keep individuals from pinch points and other areas of harm's way.

B1: On the body positioning you want to put, since they are using remote controls, just from the standpoint of visibility where you actually have to see the machine, operate where necessary.

D: And the last one – service – we talked about technician availability, onsite or offsite availability, system for data gathering such as system for trending, oil sampling, motor amperage, preventative maintenance information and maintenance indicator so you can stop the machine in the best area for that maintenance. Are there any other metrics that you would consider?

B1: Just a way for the manufacturer to notify the buyer or end-user of any design changes from one version to the next, however that's possible. Those changes should be reviewed – maybe up in the durability part – those changes should be reviewed up front.

D: So communication on design, but also design change approval?

B1: Yes, design change notification and review of system changes. Like I said for the Cat seal change we'll find that out after the fact. We'll find out there was a design change and it will cause a problem once the machine was installed.

D: And we were not part of that for review or notification until we found the problem.

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B1: All we have to do is have a list of the design modifications or changes. When you have that list you can look for check the list and find out what the problem is.

D: Really, just a collaborative effort on the part of the buyer and supplier.

B1: Especially where we go from version to version to version or upgrade.

D: Right - on a new machine or a rebuild.

B1: Right.

D: The second item in the study was a commodity – and in the commodity of roof control we've narrowed it down to roof control products for the study and really the same questions – what sourcing supplier selection would you use, why, how would you define these metrics and what definitional dimensions would you assign to these metrics and what weight of importance or what rank of importance would you assign to these metrics, which reminds me, we need to rank on the shearing machine itself, the five metrics on the shearing machine itself before we get into the commodities, so what rank order, the same as you gave them or would you change that rank order?

B1: I would change it a little bit – I think the engineering part is #1, that's where we have the first shot of improving the machine.

D: Quality – durability?

B1: Yes, quality and durability, which includes engineering. And that relays back to safety aspect of the machine so I'd say safety has to be #2. From an engineering standpoint you're going to engineer some safety in it anyway. I think the rest can stay the same.

D: So availability is third, economics fourth and service if five. Now we would start on the metrics for the roof control products.

B1: Well, roof control products – again we better get to design and application of each product and so the provider will have to show that they have enough knowledge of the geology that each product is being applied to so that goes with geo-technical engineering and the application of maybe not a specific product, but the application and design for a specific product. Case in point there, the grade of the steel that's necessary, where a softer grade of material may be necessary for roof geology that yields, the yield system and a higher grade of steel for a system that doesn't yield, that needs to be laminated in order to fit the beam. We found that that's a very important aspect and has been a very important aspect first of all from the geo-technical design. That would be the first metric. Second metric is going to be the actual type of appliance used in order first of all to provide enough safety factors, put that in there – an acceptable amount of safety factor or safety design factor for the loading that's anticipated for the roof bolt to suspend. I'm being a little technical here, but it's very important that we look at it.

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D: That's okay. So I put the metric as safety and the first definitional dimension the load safety actor.

B1: Again, I'm always going to throw the engineering part in there first because once you engineer it then you can start applying safety factors and begin looking at the safety aspect. So the unit has to be able to support its are a of influence based on a safety factor that we have designed and the manufacturer recommends and once you get to that point then you can start looking at the material itself and the configuration of the roof support. So then another metric is I guess I want to say variability, but selection – you just don't want to have one size fits all, you want to have somebody that can provide a selection of different materials and configurations so that you can at some point first of all optimize and meet the safety factor but also get to the economics of the material cost itself. So you want to optimize your strength of the appliance and also the cost.

D: So as the metric I put availability and the first definitional dimension is product selection – what can they do for us, what can they make for us?

B1: And what can you optimize in conjunction with bolts, plates, shraps, everything tied together. Then it's the speed of installation. How easy is it to install, how simple is the design system and how fast can it be installed to achieve at least 100% of its design capability.

D: So install speed is a definitional dimension. What metric would you put that in?

B1: The metric would be is if it's a one-piece unit, a two-piece unit, how fast can you couple two pieces together, how does it – what type of a hinker system does it use, the glue, so the definitional dimensions are going to be fast coupling time, fast resin time, fast anchor time and then the assurance, the simplicity that you know the system is being installed properly, even though you know it's installed fast. The optimization is critical with all these metrics because you see some manufacturers try to get a smaller diameter of material that's got a higher grade steel in it because it will support more weight in a smaller diameter, but that doesn't fit a lot of times in the front end application, the design application so everything has to be optimized. Another case history – two different roof control systems on the same section with the different appliances to go with each system can get confused by the operators. So simplicity and standardization is important, too. That's one of the definitional dimensions, too – simplicity and standardization, both the bolting material and the anchor material. We've had a few glitches there from different resins or different bolts aren't the same and when you mix the two it can be disastrous.

D: These install speed anchors system, coupling time, install technique, design optimization, standardization and simplicity, would they go with the design application metric as definitional dimensions of that?

B1: No, they'd go more toward the actual installation and the economic evaluation.

D: Okay – economic.

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B1: Yes. They'd be more economic. That's the speed, and then minimization of waste. And that all comes down to the simplicity of the installation. And then the longevity. Longevity is considered just how long the support has to last. So the longevity of the life of the support unit has to be considered too because in one case we don't want to be putting a support that lasts five-years into a 15 year area or vice versa

D: Now would that be – which metric would you put that under?

B1: I think under the engineering. You know that's part of the selection, too, what we're buying. And we're pretty sophisticated now in determining exactly what we should put in each area. Even as sophisticated as we are, one of the things we didn't really see maybe in some respects is how long will we have to use a certain area of the mine.

D: So length of service of that product actually to control the roof.

B1: Longevity. And durability again, from a durability from the standpoint whether you want a regular mild steel application.

D: So we have four metrics so far for the roof control – design and application, safety, availability and economic evaluation and the definitional dimensions we've talked about for design are geo-technical, steel grade, length of service/durability and then the safety we talked about was load safety factor and then availability was product selection evaluation, installation speed, anchor system, coupling time, install technique, design optimization, standardization, simplicity of use and waste minimization. Under simplicity of use, how would you …

B1: Material handling. From the delivery point on the surface until you get it loaded on the miner bolter or the bolters. Simplicity of use is a matter of if you could just install one piece or a couple of pieces and be done with it it's going to be faster, it's going to be more simple, less time required to put a couple of pieces together and less opportunities for mistake, so that's simplicity of use.

D: So you would evaluate the offering almost – a product offering – if they can provide you with a simple system - then.it's added value.

B1: There's no, "I have to thread it six times so I make sure I don't break this little pin, I have to make sure it has this much torque." You just put a bolt in and you're done with it and it does everything for you – the simpler the better.

D: Okay. Any other metrics that you would use other than those four?

B1: The additional bolting supplies like the rib pins, the mesh – that type of thing we use to wrap the pillars in – again, simplicity of installation and of course the economics, the cost per foot of installed mesh, that type of thing, so the economics not only for the primary supports, but also the additional support that's now become part of our entry control systems, ground control systems. It's not so much roof, but ground control support.

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D: And the cost per foot you could look at either with the secondary or primary roof support – you would look at that?

B1: Yes.

D: Now the rank order, I shouldn't say the rank order, the order we discussed was design and application safety, availability, and economic evaluation. Would you have a different rank order?

B1: That's pretty much the order they would be in. It's very important to get the engineering up front, make sure we have the right application and any time we decide to change that needs to be done, which we normally do pretty effectively with the manufacturer.

D: Okay. That's it for the two metrics. The fourth question I have is do you believe that the metrics used for strategic sourcing supplier selection are the same among the buyers, suppliers and end-users and why or why not?

B1: On these two examples specifically, or just overall?

D: In general. These two examples and in general.

B1: For these two examples you can boil it down to five or six items that we just looked at – engineering or specifications being the first one and the safety factors or the safety designs incorporated and then again the application considerations and the efficiency of the application and design which starts with cost analysis and of course the optimization of the system to get to the lowest most cost effective way per foot. You could have a more robust system and maybe a higher priced system, but your cost per foot would be the same as a smaller system and you could probably install less units for the same cost.

D: And, Buyer, when you look at those five or six metrics that we talked about – when you consider buyers being supply chain management and executive management and suppliers being the design engineers and the guys trying to sell it and the end-users being the operators and the mine managers, do you think today that those metrics are looked at the same by those three and why or why not?

B1: I think that the metrics are the same. I think the weighting and the emphasis on each metric may be different and specific areas that are involved in the selection process - whether it be engineering or procurement –and some of the safety groups – whoever gets and the maintenance groups – whoever gets involved – are going to prioritize their area a littler bit higher than the general view that we've taken, but ultimately all the metrics need to be considered before the end selection is made and if they are considered then the high probability of selecting the most cost effective and safest and most productive will be made. I think they're the same, it's just how much emphasis you put on each one. That's why we use more than one group to decide – get everyone's input.

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D: The final question is do you believe that there is a value to having these strategic sourcing supplier selection metrics and why or why not?

B1: We definitely need to do that and I went into that a little bit already, but the why is because we can always do better and we have some minor failures in selection but once the selection is made it's pretty tough to change your mind, especially when you install it ten miles underground. It's a very important process, it's not – a lot of times you don't have a second chance and investments – sometimes the investment is very high – so the real critical part is doing the analysis and putting the intelligence together before, again, the selection is made..

D: So it's critical, actually, to have a good process.

B1: Yes, very critical, and to go through each facet of the process and take your time to do it right.

D: I appreciate your taking the time. The next process will be – I have 21 to do – 7 suppliers, 7 buyers and 7 end-users. I'll analyze all and come back and say here is how I analyzed it to that point and see if you agree or disagree or how would you change them or manipulate the information to fit the way you believe it should be and in that one we would assign instead of a rank order a percent of weight of importance that obviously equals 100% for those metrics and then go back and analyze that data and then the third phase would be simply a scale that says do you agree or disagree with the final list of metrics, the weights of importance that are assigned and how they're defined amongst those three groups.

B1: Excellent.

D: Again, I greatly appreciate it.

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