Managing Supply Risk with Early Supplier Involvement: A Case Study and Research Propositions

AUTHORS

George A. Zsidisin

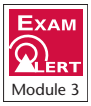
is an assistant professor of supply chain management in the Eli Broad Graduate School of Management, Michigan State University, East Lansing, Michigan.

Michael E. Smith

is an assistant professor of management and international business at Western Carolina University, Cullowhee, North Carolina.

SUMMARY

While there have been numerous reports of benefits associated with adoption of early supplier involvement (ESI) in product design, particularly in reducing the duration of the design process and improving design outcomes, this study extends a recent stream of research indicating that ESI may be a useful tool for managing supply risk. Utilizing a case-study approach, the current research explores the extent to which ESI reduces the likelihood of supply disruptions and other negative supply events for an aerospace supplier. Although initial adoption of ESI was intended to reduce supply costs, results indicated that ESI serves to reduce perceptions of supply risk at this firm. Factors associated with risk reductions are discussed in the context of agency theoretic variables, and a series of research propositions are presented to build theory in supply risk management.



INTRODUCTION

Many practitioners and academicians tout concurrent engineering (Sobek, Ward and Liker 1999; Koufteros, Vonderembse and Doll 2001, 2002; Gerwin and Barrowman 2002) and three-dimensional concurrent engineering (3DCE) (Fine 1998, 2000; Varley 1999; Balasubramanian 2001) as essential tools for new product development success. As a result, proactive purchasing organizations increasingly view coordination with critical suppliers in early supplier involvement (ESI) as important enablers to product, process and supply chain structure development (Wynstra, VanWeele and Weggemann 2001; Millson and Wilemon 2002). ESI is a form of collaboration in which purchasing firms involve suppliers at an early stage in the life cycle of a product, generally at the time of product concept or design (Bidault, Despres and Butler 1998; LaBahn 2000). However, adopting ESI practices may offer organizations additional benefits as well, potentially including the management of supply risk in new product development and the upstream supply chain.

The purpose of this paper is to investigate the role of ESI in managing supply risk. The linkage of ESI and supply risk management is investigated by conducting an in-depth case study for theory development (Eisenhardt 1989b). For purposes of this paper, supply risk is defined as the potential occurrence of events associated with inbound supply that can have significant detrimental effects for the purchasing firm (Zsidisin 2003). First, ESI is introduced along with explication of the positive and negative aspects that have been attributed to its use. Next, agency theory is introduced as a basis for investigating how ESI can benefit a firm's supply chains by enabling more effective management of various facets of risk. Given ESI is rooted in the interface between a purchasing organization and critical supplier(s), and thus presents relationships in which one organization (the supplier, viewed as an agent in this context) is working to meet needs of another (the buyer, viewed as the principal in this context), agency theory offers a useful conceptual foundation on which to build the paper. A comprehensive

case study was the key vehicle to investigate the role of ESI in supply chain performance. The selected firm had a history of success in using ESI as an integral part of supply chain strategy. The organization of the paper includes the presentation of the case study research method, discussion of findings, followed by propositions grounded in agency theory. The propositions offer suggestions for further study into how firms can reduce the risk inherent in new product development processes. The final section includes conclusions and managerial implications.

LITERATURE REVIEW

Benefits and Drawbacks of ESI

Some scholars have defined ESI as "a form of vertical cooperation where manufacturers involve suppliers at an early stage in the product development/innovation process, generally at the level of concept and design" (Bidault et al. 1998, p. 719). This concept has been also tested empirically as an integral part of concurrent engineering (Koufteros et al. 2001, 2002). Prior research has shown that ESI offers a plethora of benefits. Some of these benefits include reducing new product development times (Rigby 1996; Hartley, Zirger and Kamath 1997a; Stundza 1998; McGinnis and Vallopra 1999; Callahan and Moretton 2001; Wynstra et al. 2001); improving product quality (Minahan 1997; McGinnis and Vallopra 1999; Milligan 1999); utilizing supplier technological expertise (Wasti and Liker 1997; Vonderembse and Tracey 1999; LaBahn 2000; Wynstra et al. 2001) and managing cost (Rigby 1996; Hartley, Meredith, McCutcheon and Kamath 1997b; McGinnis and Vallopra 1999). However, not all firms have realized benefits from engaging in ESI. Some of the more notable drawbacks of ESI include increasing product and development costs (Birou and Fawcett 1994; Wynstra et al. 2001); improper sequencing of tasks (Laseter and Ramdas 2002); mismatching resources and requirements by implementing levels of supplier involvement inappropriate to the situation at hand (Bidault et al. 1998; Laseter and Ramdas 2002); failing to anticipate and effectively address significant organizational resistance (Wynstra et al. 2001) and selecting incapable suppliers (Wynstra et al. 2001). These benefits and drawbacks are summarized in Table I.

Recent attention has been directed toward additional benefits of ESI associated with the risk of product and supplier failures. More specifically, these failures may include quality problems, supplier insolvency and product introduction delays. The risk of product failures in new product development can be manifested in terms of excessive costs (Balasubramanian 2001), quality problems (Koufteros et al. 2002) and extended product design lead-times (Droge, Jayaram and Vickery 2000). On the other hand, firms can engage in ESI to reduce the risk of supplier failures, such as those with low levels of technological sophistication (Wasti and Liker 1997; LaBahn 2000) and supplier leadership problems (Ragatz, Handfield and Scannell 1997). Principles of agency theory are appropriate for investigating interorganizational relationships, and can give insight as to how ESI can serve as a supply risk management tool.

An Agency Theory Perspective of ESI

Agency theory has seen broad application in models of organizational strategic behavior, but there has been

Table I

SUMMARY OF BENEFITS AND DRAWBACKS OF EARLY SUPPLIER INVOLVEMENT

	References
Benefits	
Reduction of product development cycle times	Wynstra et al. (2001), Rigby (1996), McGinnis and Vallopra (1999), Stundza (1998), Callahan and Moretton (2001), Jayaram, Vickery and Droge (2000)
Improvement of product quality	Minahan (1997), McGinnis and Vallopra (1999), Milligan (1999), Koufteros et al. (2002)
Utilization of supplier technological expertise	LaBahn (2000), Wynstra et al. (2001), Wasti and Liker (1997), Vonderembse and Tracey (1999)
Management of cost	Hartley et al. (1997b), Rigby (1996), McGinnis and Vallopra (1999)
Drawbacks	
Increase of product and development costs	Birou and Fawcett (1994), Wynstra et al. (2001)
Improper sequencing of tasks	Laseter and Ramdas (2002)
Incorrect level of supplier involvement	Bidault et al. (1998), Laseter and Ramdas (2002)
Organizational resistance	Wynstra et al. (2001)
Selection of incapable suppliers	Wynstra et al. (2001)

limited application in the realm of organizational risk (Bromiley, Miller and Rau 2001). However, agency theory has recently been extended to the study of supply risk (Zsidisin and Ellram 2003), and provides a useful framework for understanding efforts and approaches to supply risk reduction.

Agency theory applies to the study of problems arising when one party, the principal, delegates work to another party, the agent (Eisenhardt 1989a; Lassar and Kerr 1996). The unit of analysis is the *metaphor* of a contract between the agent and the principal. In the buyer–supplier dyad, the purchasing organization serves as the principal and the supplier as the agent. Thus, an agency-theoretic analysis with respect to such relationships focuses on the means purchasing organizations use to evaluate or manage supplier performance. Supply management organizations can utilize various strategies to modify the outcomes and behaviors of suppliers in response to these variables.

Outcome-based management reflects the extent to which purchasing organizations emphasize results and is an efficient method for supervising suppliers when risk is negligible (Eisenhardt 1989a). Complete reliance on outcomes signifies an exclusive concern with bottom-line results, regardless of how agents achieve them (Choi and Liker 1995). *Behavior-based management*, on the other hand, focuses on processes and reflects the extent to which principals emphasize ''tasks and activities'' that lead to risk reduction (Eisenhardt 1989a). Evaluating supplier (agent) processes often requires substantial human and financial resources and close communication in order to improve those processes. Such improvements in processes diminish the likelihood of problems arising, therefore reducing the probability of risk materialization (Celly and Frazier 1996).

The focus of agency theory is the trade-off between the cost of managing behavior and the cost of measuring outcomes that have the effect of transferring risk to the agent. Agency theory argues that as uncertainty becomes insignificant, outcome-based management efforts are appropriate (Eisenhardt 1989a; Lassar and Kerr 1996; Logan 2000). A purchasing organization does not need to intercede by managing risk with ESI when, given the design of the new product, the probability of a detrimental supply event is low. For example, products classified as noncritical items (Kraljic 1983) would not be likely candidates for extensive risk-management efforts by means of ESI as such items generally have a relatively high degree of certainty with respect to demand volume, technology and supply chain structure. Supply risk becomes a significant issue when purchasing firms pursue a strategy based on providing innovative products, such as those designed during new product development, and when the purchased subassemblies are complex (Laseter and Ramdas 2002). When supply risk becomes a central factor, purchasing organizations need to embrace behavior-based techniques that reduce the probability that detrimental events occur. ESI may serve as a behavior-based supplier management technique, functioning to reduce the likelihood of supply risk occurrence from issues such as design flaws, extended development times and cost overruns.

From an agency theory perspective, factors that influence the choice of the approaches and efforts expended in supplier management efforts by purchasing organizations include information systems, outcome uncertainty, risk aversion, programmability, relationship length, goal congruence, adverse selection and moral hazard (Eisenhardt 1989a; Celly and Frazier 1996; Lassar and Kerr 1996; Logan 2000). These variables are briefly defined and their application to supply risk in the context of ESI is summarized in Table II.

The variables associated with agency theory should be expected to guide managerial selection of methods to reduce supply risk, and impact managerial efforts with respect to monitoring supplier performance. Thus, the agency theory variables listed in Table II provide a framework for investigating how ESI can facilitate supply risk management in new product development. For example, the implementation of ESI is proposed to reduce the threats of selecting suppliers that shirk in their contractual obligations (moral hazard), which subsequently reduces the purchasing firms risk of supplier failures during new product development.

When the required conditions and resources are present, ESI may provide both purchasing organizations and participating suppliers with significant benefits during and subsequent to new product development. Advantage may be found in areas such as improved technology, shorter product development cycle time, lower cost and higher quality. Prior research has also shown that ESI does not always manifest into organizational benefits, and at times, can even contribute additional problems. An agency-theory perspective on supply risk can serve to illuminate specific situations wherein ESI may help purchasing organizations better manage and monitor relationships with suppliers.

The remainder of the paper describes the case study research method and the use of this method to elucidate how ESI helps Rolls-Royce (RR) (aerospace division) manage risk, and the organizational benefits attained from such efforts. From the insights obtained in the case study, we then provide a series of propositions grounded in agency theory that serve to encapsulate key findings and provide bases for future research. The final section addresses managerial implications and conclusions.

RESEARCH METHOD

The research process consisted of conducting a case study within the Supply Chain Management

Table II

AGENCY THEORY VARIABLES

Variable	Definition	Application to ESI	References
Information systems	Approaches for accumulation, processing and dissemination of information	Such systems facilitate monitoring and provision of the information necessary for ESI	Eisenhardt (1989a), Ellram (1991), Wasti and Liker (1997), Lee, Padmanabhan and Whang (1997), Fine (1998)
Outcome uncertainty	Degree of uncertainty about obtaining desired results	New product designs have a higher degree of perceived risk from technological know-how, production process capability, quality, and demand volume. ESI can address potential problems early in new product development.	Eisenhardt, (1989a), Wasti and Liker (1997), Koufteros et al. (2001, 2002)
Risk aversion	The extent to which a party (principal or agent) desires to avoid risk	ESI may provide for shifting risk to the supplier through requirements of initial investments of efforts and other resources by the supplier. ESI promotes ability to manage the relationship based on both behavior and outcomes, accommodating risk aversion in both parties.	Eisenhardt (1989a), Shapira (1995), Logan (2000)
Programmability	The degree to which appropriate agent behaviors can be specified in advance	ESI can provide suppliers a template of activities necessary for product development. ESI allows buyers to better monitor supplier activities.	Eisenhardt (1989a)
Relationship length	The length of time that the relationship is anticipated to endure	ESI tends to extend relationships, increasing the likelihood of goal alignment between the supplier and the buyer	Eisenhardt (1989a), Celly and Frazier (1996)
Goal congruency	The extent to which alignment exists between the goals of the principal and those of the agent	ESI promotes goal achievement to meet the final customer's product/service requirements. ESI provides outcome clarity early in the product development phase.	Eisenhardt (1989a), Hartley et al. (1997b), Wynstra et al. (2001)
Adverse selection and moral hazard	Adverse selection is the misrepresentation of an agent's abilities that results in its selection. Moral hazard occurs when an agent fails to expend the required efforts to meet the principal's requirements.	Formal supplier selection process as part of ESI may allow for understanding a supplier's capabilities. The close working relationship implicit in ESI may support better monitoring of supplier efforts.	Eisenhardt (1989a), Kannan and Tan (2002), Baiman, Fischer and Rajan (2000)

(SCM) unit of RR. This organization was selected because it has implemented extensive ESI activities and it functions in an industry where the risk associated with supplier firms can have significant detrimental effects on the performance of the organization.

Yin (1994) suggests a single-case study is appropriate when it (1) represents a ''critical case'' in testing a well-formulated theory; (2) consists of an extreme or unique case or (3) is considered a revelatory case where the investigator(s) have the opportunity to observe and analyze a phenomenon previously inaccessible to scientific investigation. Additionally, single case studies have been justified as an appropriate method for theory development (Eisenhardt 1989b; Stuart, McCutcheon, Handfield, McLachlin and Samson 2002). Because of the conflicting findings of ESI benefits, a singular ''Effective Practice'' case study was chosen to propose *how* and *why* (Yin 1994; Ellram 1996) ESI affects organizational performance in terms of managing supply risk.

The case study firm was screened initially through a face-to-face interview, and then subsequent e-mail and telephone conversations. A case study research protocol (presented in Appendix), based upon research and conceptual discussions presented in the previously reviewed literature, was created prior to data collection conducted at one of RR's production facilities. Information-gathering techniques implemented during execution of the case study included obtaining historical data and documentation, as well as conducting structured interviews with various professional supply management personnel and other key informants.

Data generated through interviews were subjected to open, axial and selective coding analysis, in accordance with the guidelines set by Yin (1994), Miles and Huberman (1984) and Strauss and Corbin (1998). Open coding breaks down case study data in order to analyze, conceptualize and develop categories for the data. Axial coding is a technique that makes connections among categories, groups issues developed during first-level coding, and summarizes the issues into themes. Selective coding consists of integrating the research findings into an overall theory, which was grounded in agency theory (Eisenhardt 1989b) for the current study.

RESEARCH FINDINGS

The research consisted of conducting a single case study that exemplifies effective organizational practice of ESI and examines how that practice facilitates supply risk management. Initially, organizational background information is presented, followed by a description of the ESI process at RR and an introduction to the supply risk factors perceived by the case study respondents.

Organization Background

The Aerospace Division of Rolls-Royce is a major supplier of critical components in the aerospace industry, providing vital technology for civilian and military aircraft. The industry is cost and reliability driven, and requires extensive research and development. RR's products represent significant cost and safety contributions to the aircraft where they are installed, and require extensive sustained product development efforts, often taking 3–4 years and with total investments of $500–600 million before returns are realized. Further, supplier-provided components represent approximately 65–80 percent of the value of RR's products.

A newly hired purchasing executive introduced the ESI initiative to RR in 1999. Since that time, ESI has come to be considered a critical activity for RR, as it has been estimated that 80 percent of its products costs are locked in during the design phase. ESI is perceived as a vehicle for RR to meet its goal of significant cost reductions in new products. Organizational benefits from ESI include obtaining leverage with the supply base, improving design capabilities, instituting internal documentation of best practices for organizational learning and managing supply risk.

ESI at RR

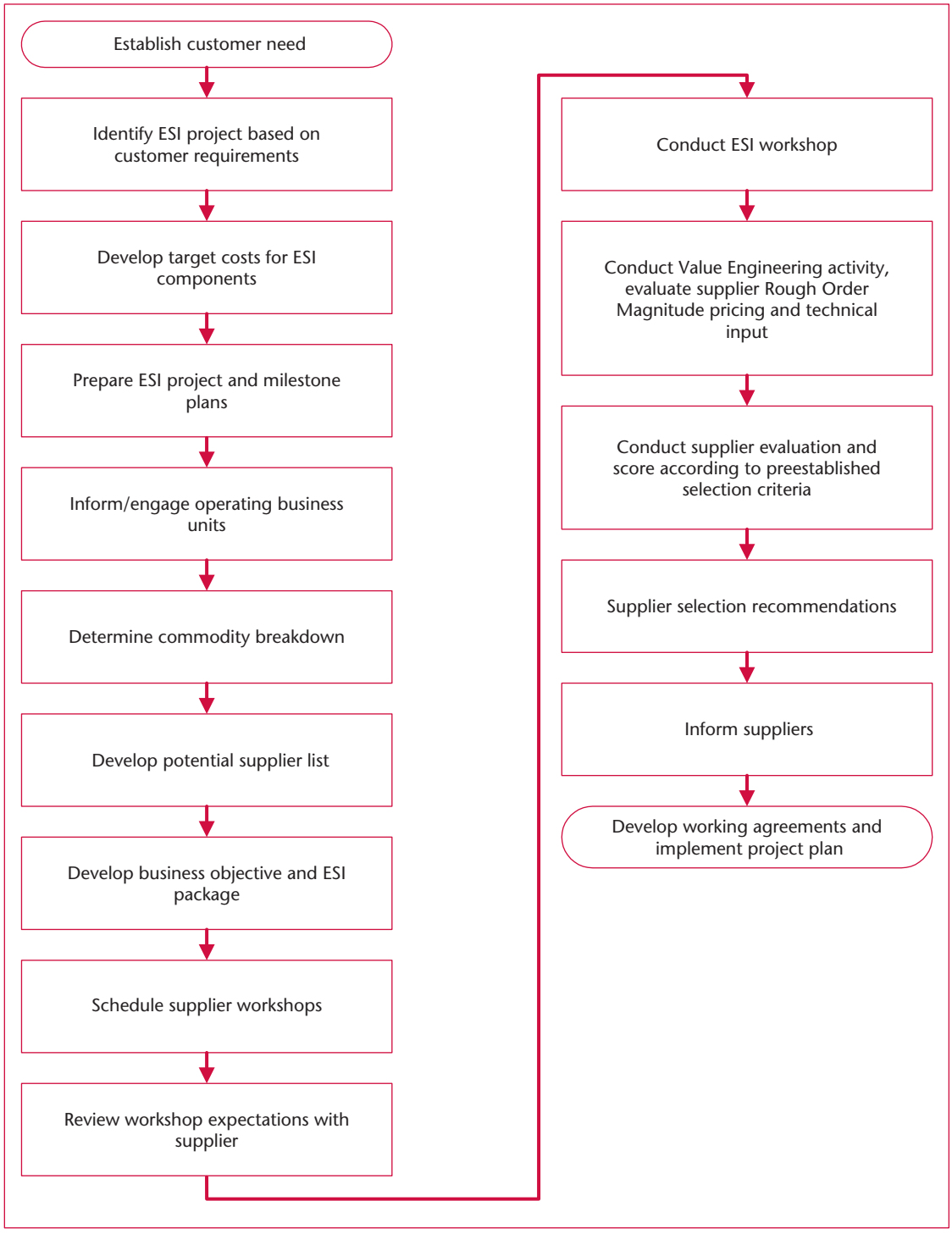
ESI at RR is based and supported in the SCM department, and operates as a support function to the various business units. Internal documents at RR present ESI as a process that engages potential suppliers in the concept design stage of new product development in order to ensure meeting customers' functional requirements for the product at the lowest possible cost across the entire life cycle. The ESI process at RR involves a 16-step process, as shown in Figure 1. The ESI process begins with establishing critical customer needs, which allows RR personnel to identify projects appropriate for ESI. Generally, the earlier in the product design cycle that ESI is implemented, the greater the potential benefits. A detailed description of this process is discussed by Smith and Zsidisin (2002). The new product development process time in the aerospace industry has been reported to last between 10 and 20 years (Fine 1998). However, most other industries have much shorter NPD timeframes, such as the automotive (4–6 years) and computer (less than 6 months) industries.

Interviews with six managers at RR revealed a number of characteristics of ESI that help to reduce supply risk, particularly with respect to risk originating with suppliers. These findings were further refined in representations from 12 first-tier suppliers during a supplier conference hosted by RR. Issues impacted by ESI that significantly influence supply risk perceptions include the threats of excessive cost, legal liabilities, quality problems, supplier capacity constraints, extended product development times, the inability to handle product design changes and supplier organizational leadership issues. Table III summarizes findings with respect to these characteristics.

Excessive costs were a major impetus for the ESI initiative at RR. Prior to the initiative, the perception among RR officials was that they were being priced out of an increasingly competitive marketplace. This led RR to

Figure 1

EARLY SUPPLY INVOLVEMENT PROCESS MODEL AS DEVELOPED BY ROLLS-ROYCE



invoke target costing as a major component of ESI. Further, RR has found that "world class" suppliers generally have cost reduction programs in place. However, this is not the case with less competent suppliers. ESI has provided RR with means for working with suppliers both to convince them of the importance of cost reduction programs, and to help suppliers develop these programs when they do not exist. As the ESI initiative has matured, and RR has developed a solid supply base, RR increasingly fashioned a cadre of suppliers and an approach to working together that assures continued cost reductions in design and redesign efforts. As the result of developing effective

Table III

HOW ESI REDUCES SUPPLY RISK AT ROLLS-ROYCE

Risk Source	ESI Management of Risk
Excessive costs	Working with ''world-class'' suppliers with cost reduction programs in place Establishing target costing process within ESI
Legal liabilities	Determining intellectual property rights during initial agreements Effective sharing of expertise
Quality problems	Ensuring alignment between designs and production capabilities in the supply chain Using scorecards that track current supplier performance for determining if they are invited to participate in new ESI projects
Supplier capacity constraints	Ensuring supplier production flexibility during preselection phase of ESI Sharing future demand forecast information immediately with suppliers to improve the planning process
Extended product development times	Sharing development information, material and design changes, and resources
Inability to handle product design changes	Working with suppliers early in the product development process Having key ESI suppliers provide ''modules'' to effectively manage product integration
Supplier organizational leadership issues	Providing clarity of supplier management structures Obtaining knowledge of suppliers at both corporate and plant levels

relationships with suppliers, RR has significantly reduced perceived risks associated with noncompetitive pricing of critical supplies.

Legal liability issues represent a potentially significant risk for firms involved in developing and marketing advanced technology products. Officials at RR note that the precise form of the liability depends on which party or parties have critical expertise. Effective sharing of expertise reduces risk associated with product failure in the marketplace, and agreements that provide for the sharing of gains reduces the potential risk associated with intellectual property rights concerns. RR has found that ESI decreases both the chance that there will be legal liability issues and the resulting loss in the case of their occurrence.

Quality problems can often be resolved by ensuring alignment between designs and capabilities early in the design cycle. Concurrent design engineering between the suppliers and RR helps to ensure proactive resolution of design problems that might lead to extensive rework and yield problems. Further, by the use of scorecards such as financial appraisal reports, sole-source registers, and an ''At Risk Register'' that records data about supply-base execution, RR continuously tracks the performance of current suppliers, and can use this information in determining which suppliers will be invited to participate in new ESI projects. RR sees the effective utilization of performance data in selecting suppliers for ESI as managing the risk associated with the potential for quality problems by preventing their occurrence.

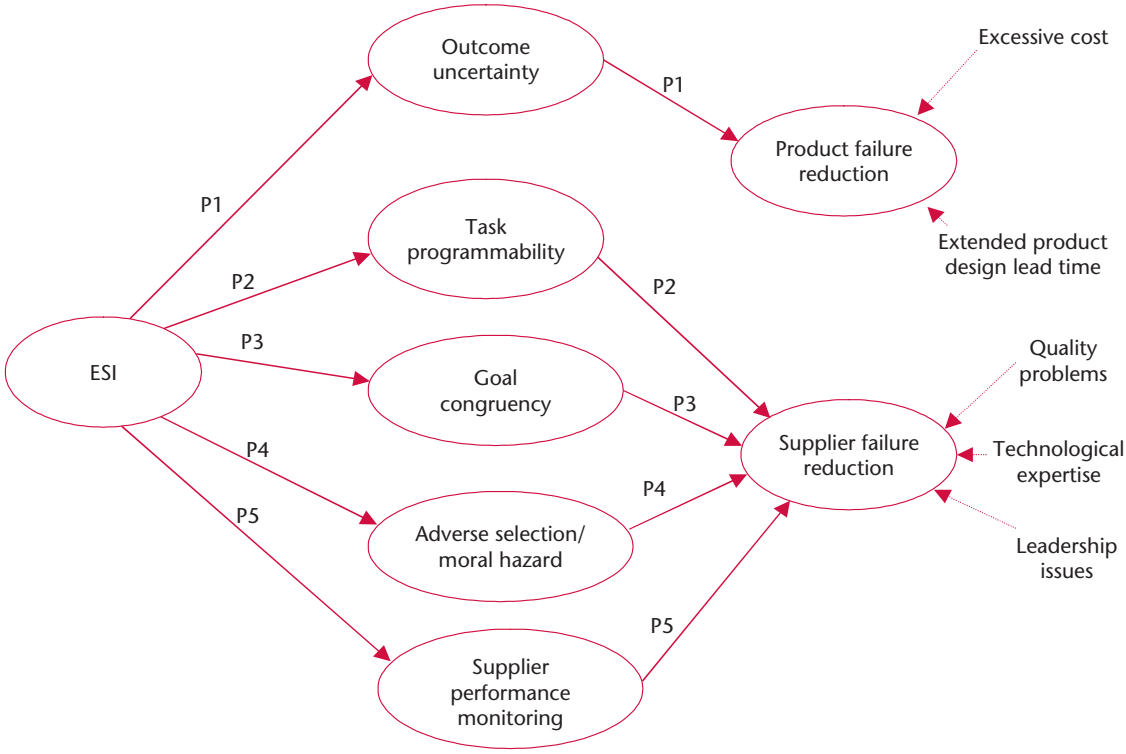
Supplier capacity constraints represent a risk associated with the production flexibility of a supplier. RR engages its suppliers during the preselection process of ESI projects in discussions about the planning process, past growth, current status and investments aimed at the suppliers future. RR views information about the planning and implementation of supplier capacity expansion as critical to their efforts to manage the risk of capacity constraints by selecting suppliers who will meet the future needs of their production processes. RR has noted that even during times of difficult economic conditions, world-class suppliers may see substantial growth and could have capacity problems. The information sharing that is part of effective ESI efforts represents a valuable means for determining the adequacy of the supplier's capacity planning, and providing the supplier with information to drive more successful planning with regard to the buying organizations future requirements.

Extended product development times represent a risk to RR in that they can increase development costs and delay the delivery of the new product into the market. ESI helps RR manage this risk by ensuring sharing of development information. Thus, delays are readily recognized, and steps can be taken to manage the process to mitigate the risk, including sharing of resources and making material and design changes.

The *inability to handle product design changes* on the part of suppliers can jeopardize the entire product line. RR has found that the information exchange that is part of the ESI process helps it manage design changes efficiently and

Figure 2

THEORETICAL MODEL OF ESI'S ROLE IN MANAGING SUPPLY RISK



effectively because awareness of budding problems allows them to develop alternate strategies.

In the context of ESI, RR has found that it can more readily identify risk associated with *supplier organizational leadership problems*. RR has found that suppliers readily provide information about their management structures during the initial stages of ESI. One particular issue that RR faced is that many potential suppliers have operations in different locations. A well-managed operation in one location does not imply that all of the suppliers operations function in a similar manner. In such cases, RR may be faced with the challenge of determining the extent to which the overall organization can be brought together to accomplish what RR needs.

PROPOSITIONS FOR FUTURE RESEARCH

When organizations and their suppliers work together as part of ESI projects, information exchange is enhanced. With better exchange of information comes knowledge of the situations surrounding the dynamics of a supply relationship, and with that knowledge comes greater potential for detecting, averting, and managing supply risk. Given the nature of RR's products, and the nature of many of the components obtained from suppliers, the

Table IV

SUMMARY OF RESEARCH PROPOSITIONS

P1	ESI reduces risk in new product development from product failures by managing outcome uncertainty.
P2	ESI reduces risk in new product development from supplier failures by programming and monitoring supplier tasks and accomplishments.
P3	ESI reduces risk in new product development from supplier failures by creating goal congruency between the purchasing and supplier organizations.
P4	ESI reduces risk in new product development from supplier failures by avoiding adverse selection and moral hazard.
P5	ESI reduces risk in new product development from supplier failures by allowing purchasing firms to better monitor supplier activities.

fact that ESI would be an effective tool in reducing perceived supply risk fits well with previous research reported by Laseter and Ramdas (2002). For example, RR purchases products characterized by: (1) having critical safety concerns and government oversight, (2) encompassing a high degree of technology content and (3) displaying substantial complexity in designing, manufacturing and sourcing. Thus, given the clusters derived by Laseter and Ramdas (2002), it is expected that early and high-level supplier involvement would be beneficial, as was found in RR's ESI process. This is because products such as aircraft jet engines and their respective parts have critical safety concerns that have significant Federal Aviation Administration (FAA) oversight, possess high levels of technological sophistication, and have complex interactions in the bill of materials. Under these circumstances, the involvement of technologically knowledgeable suppliers during the earliest stages of the product development process can provide immediate benefits in terms of reducing the time it takes to create a new design, introducing alternatives to take cost out of the designs, and providing understanding to suppliers as to how their specific subassemblies fit into the overall engine. On the other hand, integrating suppliers that provide commodity and indirect supplies early in the product design stage would not be beneficial because the value gained from ESI would not offset the significant resource investments in time and personnel.

From these research findings, we developed a series of propositions to describe how ESI reduces the supply risk of product and supplier failures, as mediated through several variables grounded from an agency theory perspective. Product failures arise from inabilities to meet consumer requirements because of cost overruns and failure to meet product launch deadlines. Supplier failures, on the other hand, stem from supplier issues such as technological problems and leadership concerns. As shown in Figure 2 and summarized in Table IV, ESI facilitates supply risk reduction for strategic, complex products through addressing agency theory variables (defined in Table II) as follows: (1) reducing outcome uncertainty, (2) providing task programmability, (3) creating goal congruency, (4) avoiding adverse selection and moral hazard and (5) monitoring supplier performance. Next, each of these propositions is presented in detail.

Reducing Outcome Uncertainty

ESI reduces the outcome uncertainty associated with outsourcing the production of a subcomponent. Having suppliers involved early within the product design process reduces the risk of product failures associated with not achieving target costs and extending product design lead times by integrating product, process and supply chain design through ESI. Implementing ESI with strategic supply sources allows buyer and supplier organizations to work together in deriving solutions to outcome uncertainty from volume demand fluctuations and technological advancements.

Proposition 1: ESI reduces risk in new product development from product failures by managing outcome uncertainty.

Creating Task Programmability

An established ESI program can provide suppliers a template of activities necessary for the achievement of new product development success. At RR, task programmability is accomplished using target costing and initial meetings with supplier organizations. The target costing process begins with a breakdown of allowable supplier costs. RR provides aggressive target cost goals for its suppliers, and relies upon its suppliers to provide suggestions before the product design is solidified in order to achieve predetermined target cost goals. The sharing of target costs presents suppliers with a clear goal. In the past, the predominant focus in the aerospace industry has been on quality and reliability, and while RR continues to focus on these attributes, the use of target costs follows RR's realization that it must also address costs in order to remain competitive in this industry.

Outcome expectations are also provided to suppliers during the preselection phase of the ESI process. After signing nondisclosure agreements, suppliers are provided a briefing of what will be expected of them, such as target costs based on rough order of magnitude estimates for the required tasks, requirements to be met in creating design specifications, and willingness to work with suggested second-tier suppliers. These outcome expectations are continuously monitored throughout the design development phase as a function of supplier personnel being colocated at RR's plants, and during quarterly meetings to review supplier issues perceived as potential risks.

Proposition 2: ESI reduces risk in new product development from supplier failures by programming and monitoring supplier tasks and accomplishments.

Creating Goal Congruency

Within the context of this case, ESI initially provides an outcome-based method for controlling or managing supplier behaviors. Before the supplier selection decision, there is often no close relationship specified between RR and its potential suppliers. The purpose of ESI at the presupplier selection phase is to determine which suppliers will be best able to meet the specified outcomes in terms of quality, delivery, cost, technology and time-line goals. However, in addition to managing toward specific outcomes, RR also includes managerial aspects that are readily related to behavior-based management technologies or methods. During the initial stages of ESI,

before the actual supplier is selected, RR is most interested in understanding the culture and philosophies of each of the supplier organizations. This is because it is important for RR to see that there will be goal congruency between the two organizations, and that the philosophies and organizational cultures provide for a sound match. In addition, after making the supplier selection decision, it is expected that a close relationship that is characterized by the exchange of critical, timely, and sensitive information will arise and that the relationship between the two firms will continue for a long period.

Proposition 3: ESI reduces risk in new product development from supplier failures by creating goal congruency between the purchasing and supplier organizations.

Avoiding Adverse Selection and Moral Hazard

The ESI process also provides for managing the risks of adverse selection and moral hazard. By having suppliers involved at the earliest stages of the new product development cycle, RR is better assured that it will select the most qualified supplier. RR expects that these suppliers will bring engineering expertise to an aircraft subassembly, have an outstanding reputation for quality, and possess a similar corporate philosophy to that of RR. In addition, as the product development process is rather lengthy, the suppliers involved in an ESI project must initially demonstrate a significant level of commitment and provide clear indication that this level of commitment will be sustained. If they are selected and consistently meet performance requirements, suppliers will enjoy an assurance of continued business on a large scale. Suppliers that either cannot meet requirements up-front or are not willing to put forth the required effort to meet RR demands are eliminated from further consideration early within the process, which reduces the threats of adverse selection and moral hazard.

In sum, eliminating the chance that RR selects the wrong supplier reduces its exposure to supply risk. Throughout the ESI process, when investigating which firm to select for a specific subclass of items, RR is able to obtain initial insights into which firms represent "world-class" suppliers. From a supply chain perspective, this facilitates concurrent product, process and supply chain design (Fine 1998) by evaluating and selecting the most capable suppliers available. By involving multiple suppliers from the initial stages of product conception, the supplier selection process at RR is able to gather information about those suppliers philosophies, technological and production capabilities, past experience and desired goals. However, this may or may not exist in other industries, because of factors such as historical buyer–supplier relationships that affect the extent of trust that exists between buying and supplying organizations and technological sophistication of the products produced. Specifically, the level of trust and past experience can provide the purchasing organization information as to whether or not adverse selection and moral hazard are prevalent in a respective industry. In addition, if the products produced are not technologically sophisticated, the threats of moral hazard and adverse selection are reduced because the reasons for supplier nonperformance become readily apparent. In the case of RR, many of the supply risk factors that can exist are effectively managed early in the process. This portion of RR's ESI process facilitates selecting either a world-class supplier, or one that is attempting to attain that status.

Proposition 4: ESI reduces risk in new product development from supplier failures by avoiding adverse selection and moral hazard.

Monitoring Supplier Performance

Prior to initiating an ESI project there is considerable uncertainty about potential suppliers, their capabilities, the exact nature of the actions required to obtain desired outcomes, and even the precise outcomes to be obtained, other than the previously established target costs. At RR, initial relationship management initiatives are dominated by the outcomes established by target costing. However, as the relationship progresses during and after supplier selection, greater clarity develops about the supplier, including supplier capabilities and intentions, and about the project, including actions required and the precise description of the desired outcomes. Together with the close working relationship implicit in ESI, the additional clarity renders behavior-based monitoring readily part of routine interactions with the supplier, and substantially assures obtaining the desired outcomes. Positive results over a period help to promote trust, which can serve to enhance the working relationship as part of ESI. However, diligence requires that the purchasing organization continue to monitor supplier performance with respect to both their behaviors and outcomes, so that changes related to any of the agency theory variables can be detected and addressed.

Proposition 5: ESI reduces risk in new product development from supplier failures by allowing purchasing firms to better monitor supplier activities.

MANAGERIAL IMPLICATIONS

The ESI model developed by RR (Figure 1) represents an effective approach to implementing many of the conceptual features presented by Dowlatshahi (1998, 1999), and its explication provides a reasonable roadmap for overcoming implementation barriers noted by McIvor and Humphreys (2004). One particularly advantageous aspect of the current model is its focus on ESI imple-

mentation at the individual design project level that provides a method for organizations to build capacity for organizational ESI initiatives. The RR model provides conceptually appropriate sequencing of managerial activities in a generic process that can readily be adapted to many settings.

One of the key benefits of properly sequenced activities is that it allows detection of potential risks stemming from both product design and supplier performance. Early involvement of the right suppliers in product design promotes utilization of the best expertise available in individual design and specification decisions. Thus, potential for product failure is minimized by problem prevention rather than through remediation. However, collaborative efforts also promote early detection and correction of problems in the design as they develop, considerably reducing costs associated with implementing required changes later in the product life cycle. These properties of interorganizational concurrent design mirror findings in concurrent design at the organizational level. However, such advantages can only be obtained where well-founded trust and effective communication are prevalent.

The development and effective monitoring of collaborative relationships are critical to both reducing the potential for supplier failure and reducing the magnitude of harm should such failure be realized. The ESI model implemented at RR emphasizes the value of sequencing activities to select the best suppliers, establishing effective communication and using appropriate oversight that is relevant to the stage of development for the buyer–supplier relationship. ESI can be effective in preventing problems with supplier performance.

The ESI model implemented at RR is relatively straightforward from a conceptual perspective and effective from a performance perspective (Smith and Zsidisin 2002), as well as from a risk-management viewpoint. This model may represent a reasonable initial guide for organizations considering implementing ESI, and provides a general framework for organizations to utilize in modifying the current model, or in developing new models, to fit their unique business environment.

CONCLUSIONS

By selecting the proper suppliers using an exhaustive selection process, and then by developing solid information exchange within the context of a developing relationship with selected suppliers, RR has shown that it can substantially reduce supply risk. Although cost reduction was the original impetus behind the implementation of ESI within RR, it has been instrumental in substantially reducing the risk associated with products and suppliers in new product development.

This case study has also demonstrated that aspects of agency theory are applicable to studying the relationship between purchasing organizations and supplier firms. Specifically, the purchasing organization (the principal) hires a supplier firm (the agent) to perform specified tasks, such as the design, production, and delivery of a subassembly or component at a specified price and quantity. This relationship between the two firms becomes more complex when the product itself is not tangible, such as in the instance of suppliers bringing engineering and product design expertise to their customers. Aspects of agency theory that provide better insights into managing supply risk through ESI are outcome uncertainty, task programmability, goal congruency, adverse selection and moral hazard and supplier performance monitoring. Understanding the influence of these variables in new product development can result in reducing the risk from product failures in terms of cost and lead times, and from supplier failures with regard to quality problems, technological capabilities, and leadership issues. As was previously observed for channel relationships (Celly and Frazier 1996), a combination of outcome- and behavior-based control methods may prove most effective, depending on the nature of the purchase, relationship with the supplier and risk associated with the product. Supplier management may be dominated by outcome-based approaches at first, particularly with respect to cost, and then develop toward a behavior-based orientation after the supplier selection decision is made within the ESI process. As a result, this focus on supplier actions tends to promote a strong relationship between the purchasing and supplier organizations, and is appropriate to the long-term orientation of ESI.

The major limitation of this study is that it is based upon a single case study, which has allowed elucidation of key aspects of ESI as an approach to supply risk reduction. Future research on the degree to which these findings are generalizable to other firms in the aerospace industry, other manufacturing industries, and the service sector will help clarify the extent to which supply management practitioners should be encouraged to implement ESI in order to manage supply risk. Further, research aimed at determining the applicability of the propositions that we advance should provide for extending the treatment of agency theory as a theoretical underpinning for both research and practical application in supply management. Such extensions might include further research on the benefits of ESI, including explication of industry-specific practices, or cross-sectional sampling aimed at finding shared practices. These studies may invoke research methodologies such as multiple case studies or survey-based research.

Findings from the current research show that ESI has important implications for the management of supply risk when the right conditions exist in new product

development. Agency theory appears to provide an effective lens through which to assess future research and the practical implications of supply management initiatives. Through the strategic implementation of ESI in concurrent engineering, purchasing organizations can achieve higher levels of performance by managing supply risk.

REFERENCES

Baiman, S., P.E. Fischer and M.V. Rajan. "Information, Contracting, and Quality Costs," *Management Science*, (46:6), 2000, pp. 776-789.

Balasubramanian, R. "Concurrent Engineering — A Powerful Enabler of Supply Chain Management," *Quality Progress*, (34:6), 2001, pp. 47-53.

Bidault, F., C. Despres and C. Butler. "New Product Development and Early Supplier Involvement (ESI): The Drivers of ESI Adoption," *International Journal of Technology Management*, (15:1/2), 1998, pp. 49-69.

Birou, L.M. and S.E. Fawcett. "Supplier Involvement in Integrated Product Development: A Comparison of US and European practices," *International Journal of Physical Distribution and Logistics Management*, (24:5), 1994, pp. 4-14.

Bromiley, P., K.D. Miller and D. Rau. "Risk in Strategic Management Research." In M.A. Hitt, R.E. Freeman and J.S. Harrison (Eds.), *The Blackwell Handbook of Strategic Management*, Blackwell, Oxford, 2001, pp. 259-288.

Callahan, J. and B. Moretton. "Reducing Software Product Development Time," *International Journal of Project Management*, (19:1), 2001, pp. 59-70.

Celly, K. and G. Frazier. "Outcome-Based and Behavior-Based Coordination Efforts in Channel Relationships," *Journal of Marketing Research*, (33:2), 1996, pp. 200-210.

Choi, T.Y. and J.K. Liker. "Bringing Japanese Continuous Improvement Approaches to U.S. Manufacturing: The Roles of Process Orientation and Communications," *Decision Sciences*, (26:5), 1995, pp. 589-620.

Dowlatshahi, S. "Implementing Early Supplier Involvement: A Conceptual Framework," *International Journal of Operations & Production Management*, (18:2), 1998, pp. 143-167.

Dowlatshahi, S. "Early Supplier Involvement: Theory Versus Practice," *International Journal of Production Research*, (37:18), 1999, pp. 143-167.

Droge, C., J. Jayaram and S.K. Vickery. "The Ability to Minimize the Timing of New Product Development and Introduction: An Examination of Antecedent Factors in the North American Automobile Supplier Industry," *The Journal of Product Innovation Management*, (17:1), 2000, pp. 24-40.

Eisenhardt, K.M. "Agency Theory: An Assessment and Review," *Academy of Management Review*, (14:1), 1989a, pp. 57-74.

Eisenhardt, K.M. "Building Theories from Case Study Research," *Academy of Management Review*, (14:4), 1989b, pp. 532-550.

Ellram, L.M. "Supply Chain Management: The Industrial Organisation Perspective," *International Journal of Physical Distribution and Logistics Management*, (21:1), 1991, pp. 13-22.

Ellram, L.M. "The Use of the Case Study Method in Logistics Research," *Journal of Business Logistics*, (17:2), 1996, pp. 93-138.

Fine, C.H. *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Perseus, Reading, MA, 1998.

Fine, C.H. "Clockspeed-Based Strategies for Supply Chain Design," *Production and Operations Management*, (9:3), 2000, pp. 213-221.

Gerwin, D. and N.J. Barrowman. "An Evaluation of Research on Integrated Product Development," *Management Science*, (48:7), 2002, pp. 938-953.

Hartley, J.L., J.R. Meredith, D. McCutcheon and R.R. Kamath. "Suppliers' Contribution to Product Development: An Exploratory Survey," *IEEE Transactions on Engineering Management*, (44:3), 1997b, pp. 258-267.

Hartley, J.L., B.J. Zirger and R.R. Kamath. "Managing the Buyer–Supplier Interface for On-Time Performance in Product Development," *Journal of Operations Management*, (15:1), 1997a, pp. 57-70.

Jayaram, J., S.K. Vickery and C. Droge. "The Effects of Information System Infrastructure and Process Improvements on Supply-Chain Time Performance," *International Journal of Physical Distribution & Logistics Management*, (30:3/4), 2000, pp. 314-330.

Kannan, V.R. and K.C. Tan. "Supplier Selection and Assessment: Their Impact on Business Performance," *Journal of Supply Chain Management*, (38:4), 2002, pp. 11-21.

Koufteros, X.A., M.A. Vonderembse and W.J. Doll. "Concurrent Engineering and Its Consequences," *Journal of Operations Management*, (19:1), 2001, pp. 97-115.

Koufteros, X.A., M.A. Vonderembse and W.J. Doll. "Integrated Product Development Practices and Competitive Capabilities: The Effects of Uncertainty, Equivocality, and Platform Strategy," *Journal of Operations Management*, (20:4), 2002, pp. 331-355.

Kraljic, P. "Purchasing Must Become Supply Management," *Harvard Business Review*, (61:5), 1983, pp. 109-117.

LaBahn, D.W. "Early Supplier Involvement in Customer New Product Development: A Contingency Model of Component Supplier Intention," *Journal of Business Research*, (47:3), 2000, pp. 173-190.

Laseter, T.M. and K. Ramdas. "Product Types and Supplier Roles in Product Development: An Exploratory Analysis," *IEEE Transactions on Engineering Management*, (49:2), 2002, pp. 107-118.

Lassar, W.M. and J.L. Kerr. "Strategy and Control in Supplier–Distributor Relationships: An Agency Perspective," *Strategic Management Journal*, (17:8), 1996, pp. 613-632.

Lee, H., V. Padmanabhan and S. Whang. "Information Distortion in a Supply Chain: The Bullwhip Effect," *Management Science*, (43:4), 1997, pp. 546-558.

Logan, M.S. "Using Agency Theory to Design Successful Outsourcing Relationships," *International Journal of Logistics Management*, (11:2), 2000, pp. 21-32.

McGinnis, M.A. and R.M. Vallopra. "Purchasing and Supplier Involvement in Process Improvement: A Source of Competitive Advantage," *Journal of Supply Chain Management*, (35:4), 1999, pp. 42-50.

McIvor, R. and P. Humphreys. "Early Supplier Involvement in the Design Process: Lessons from the Electronics Industry," *Omega*, (32:3), 2004, pp. 179-199.

Miles, M.B. and A.M. Huberman. *Qualitative Data Analysis: A Sourcebook of New Methods*, Sage, Beverly Hills, CA, 1984.

Milligan, B. "Get Involved Early with New Product Launches," *Purchasing*, October 21, 1999, pp. 24–26.

Millson, M.R. and D. Wilemon. "The Impact of Organizational Integration and Product Development Proficiency on Market Success," *Industrial Marketing Management*, (31:1), 2002, pp. 1-23.

Minahan, T. "Allied Signal Soars By," *Purchasing*, September 18, 1997, pp. 38–47.

Ragatz, G.L., R.B. Handfield and T.V. Scannell. "Success Factors for Integrating Suppliers Into New Product Development," *Journal of Product Innovation Management*, (14:3), 1997, pp. 190-202.

Rigby, B. "Continuous Acquisition and Life-Cycle Support: The Risks and Benefits of Early Supplier Involvement in the Development Process," *Logistics Information Management*, (9:2), 1996, pp. 22-26.

Shapira, Z. *Risk Taking: A Managerial Perspective*, Russell Sage Foundation, New York, 1995.

Smith, M.E. and G.A. Zsidisin. "Early Supplier Involvement at MRD," *PRACTIX, Best Practices in Purchasing and Supply Management*, (5:4), 2002, pp. 1-5.

Sobek, W., A.C. Ward and J.K. Liker. "Toyota's Principles of Set-Based Concurrent Engineering," *Sloan Management Review*, (40:2), 1999, pp. 67-83.

Strauss, A. and J.M. Corbin. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 2nd ed., Sage, Thousand Oaks, CA, 1998.

Stuart, I., D. McCutcheon, R.B. Handfield, R. McLachlin and D. Samson. "Effective Case Research in Operations Management: A Process Perspective," *Journal of Operations Management*, (20:5), 2002, pp. 419-433.

Stundza, T. "Seeking Tomorrow's Materials Today," *Purchasing*, February 12, 1998, pp. 32S11–32S16.

Varley, P. "Plane Thinking," *Supply Management*, (4:5), 1999, pp. 39-40.

Vonderembse, M.A. and M. Tracey. "The Impact of Supplier Selection Criteria and Supplier Involvement on Manufacturing Performance," *Journal of Supply Chain Management*, (35:3), 1999, pp. 33-39.

Wasti, S.N. and J.K. Liker. "Risky Business or Competitive Power? Supplier Involvement in Japanese Product Design," *Journal of Product Innovation Management*, (14:5), 1997, pp. 337-355.

Wynstra, F., A. VanWeele and M. Weggemann. "Managing Supplier Involvement in Product Development: Three Critical Issue," *European Management Journal*, (19:2), 2001, pp. 157-167.

Yin, R.K. *Case Study Research: Design and Methods*, Sage, Thousand Oaks, CA, 1994.

Zsidisin, G.A. "Managerial Perceptions of Supply Risk," *Journal of Supply Chain Management*, (39:1), 2003, pp. 14-25.

Zsidisin, G.A. and L.M. Ellram. "An Agency Theory Investigation of Supply Risk Management," *Journal of Supply Chain Management*, (39:3), 2003, pp. 15-30.

Appendix: Research Protocol

Case Study Research Questions

1. Could you please briefly describe your individual background and position, your business unit and the industry in which your business unit operates?
2. What are the corporate and business-unit objectives? How does the purchasing and supply management function support those business objectives?
3. How long has RR been engaged in Early Supplier Involvement (ESI) activities? What led to initiation of (ESI) in product design at RR?
4. How does RR define ESI?
5. In what ways does ESI promote business success in RR's competitive business environment?
6. How does ESI contribute to your corporate/business unit objectives?
7. Could you please describe the ESI process and provide examples where possible? Is there a formal program? Is there a standardized, written procedure for ESI? If so, could we see a copy of it?
8. Is ESI pursued for new products? Is ESI pursued for changes to existing products?
9. What types of products/services are considered appropriate for ESI initiatives? Why? What types of products or services are not appropriate for ESI?
10. How many and what percentage of suppliers have been involved in ESI activities? In what product lines has ESI occurred? What projects?
11. For each of the levels indicated below, please indicate the percentage of projects that involve the suppliers in the development process at that level.

Level of Involvement	Description	Percentage of Projects
Level 1	Supplier provided input into your product/design by sharing information about its equipment and capabilities.	
Level 2	Supplier provided feedback on your design including suggestions for cost and quality improvements.	
Level 3	Supplier participates significantly in the design of a part/component by executing detailed drawings based on your group's rough sketches.	
Level 4	Supplier took full responsibility from concept to manufacture for the design of an entire part/component.	
Level 5	Supplier took full responsibility from concept to manufacture for the design of a system/subassembly incorporating one or more parts with it also designed.	

12. When do suppliers begin to participate in ESI activities? Are there prerequisites required of suppliers prior to involving them in ESI?

13. Do suppliers need to be considered strategic partners prior to consideration for ESI?
14. What have been the reactions of suppliers to ESI initiatives? Why? Has this changed over time?
15. Please describe the benefits RR has experienced from ESI. Have suppliers also benefited? How?
16. Has RR experienced any detrimental effects from implementation of ESI? If so, what were they, and what were the specific conditions that led to this? Were these situations anticipated prior to their occurrence, and are there steps that can be taken to avoid them?
17. Does ESI facilitate risk management or risk reduction in RR? If so, what sources of risk are managed or reduced? How?
18. What do you see for the future of ESI at RR?
19. Are there things that we have not asked that we should know about ESI at RR?
20. Are there other leading-edge Supply Chain Management activities at RR that you would like to tell us about?
21. Is there anything else that you would like to add?
22. Are there other individuals at RR whom we should talk to about this?

WHAT IS THE EFFECT OF ESI ON SUPPLY RISK?

Supply Risk Characteristic	**Perceived Risk**			**ESI Effect on Risk**			**How? (Use back of page if more space needed.)**
	High	Some	Low	Reduces Chance of Occurrence	Reduces Loss	Little/No Effect on Risk	
Disasters at supplier facilities	☐	☐	☐	☐	☐	☐	
Environmental performance of suppliers	☐	☐	☐	☐	☐	☐	
Global sourcing	☐	☐	☐	☐	☐	☐	
Inability of supplier to reduce cost	☐	☐	☐	☐	☐	☐	
Incompatible information systems	☐	☐	☐	☐	☐	☐	
Legal liability issues	☐	☐	☐	☐	☐	☐	
New product development	☐	☐	☐	☐	☐	☐	
Number of applications of the purchased item	☐	☐	☐	☐	☐	☐	
Number of qualified suppliers	☐	☐	☐	☐	☐	☐	
Quality problems	☐	☐	☐	☐	☐	☐	
Supplier capacity constraints	☐	☐	☐	☐	☐	☐	
Supplier inability to handle product design changes	☐	☐	☐	☐	☐	☐	
Supplier inability to handle volume/mix requirements changes	☐	☐	☐	☐	☐	☐	
Supplier market capacity constraints	☐	☐	☐	☐	☐	☐	
Supplier organizational leadership	☐	☐	☐	☐	☐	☐	
Supply market price increases	☐	☐	☐	☐	☐	☐	
Unpredictable cycle times	☐	☐	☐	☐	☐	☐	
Other _____	☐	☐	☐	☐	☐	☐	