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A Market-Based Framework for Semiconductor Industry Growth the Reduced Ecological Impart

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A MARKET-BASED FRAMEWORK FOR SEMICONDUCTOR INDUSTRY GROWTH WITH REDUCED ECOLOGICAL IMPACT

by

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ABSTRACT

An abstract of the dissertation of Dawood Sulieman Abugharbieh for the Doctor of Philosophy in Systems Science: Business Administration presented June 9, 2006.

Title: A Market-Based Framework for Semiconductor Industry Growth with Reduced Ecological Impact

Reducing the ecological impact of industrial development is an emerging trend that affords companies the opportunity to gain competitive advantage. Semiconductor manufacturers have specifically identified ecological impact as a strategic variable that presents a long-term challenge. The socioeconomic nature of the ecological impact construct increases decision-making complexity in a manner that is not typical in business-to-business contexts. To account for social and economic aspects, this study utilized a cognitive structure-based model. Such models have been successfully utilized in consumer and industrial markets as adaptable frameworks that can encompass social and economic constructs.

This research focuses on linking two ecological constructs to market outcomes: customers' belief about the usefulness of ecological product attributes and their attitude concerning the environment. Models of those relationships were proposed and tested. This involved the development of

new multiple-item scales to measure belief and attitude. The conceptualization of these scales was drawn from the literature on attitude theory and marketing. Hypotheses were tested regarding the relationships between beliefs, attitudes, and market outcomes.

A survey was formulated based on an extensive review of the literature and input from a multi-stakeholder panel. Responses came from semiconductor engineers and professionals in the US, Japan, Korea, Taiwan, Europe, and the rest of Asia. Data analyses demonstrated the achievement of valid and reliable scales that measure the ecological belief and attitude constructs.

Semiconductor makers can be segmented based on economic criteria into two groups. One group views reducing ecological impact as an opportunity and the other regards it as a cost. Each segment's beliefs and collective attitudes have significant relationships with intentions regarding new equipment adoption and the formation of joint technology development partnerships. A product factor related to the reduction of a factory's overall ecological impact was a more frequent significant predictor of customer purchase intentions than a factor related to natural resource conservation. Equipment suppliers that focus on reducing ecological impact of their tools stand to benefit from each segment if their value offerings are aligned with each group's unique needs. Such economic benefits provide a market-based incentive to reduce the ecological impact of semiconductor production tools.

DEDICATION

To my mother Wafieh and my father Sulieman. Words cannot describe what I think of your sacrifice for me. Thank you for making me the man I am and for planting Palestine in my heart. With my eternal love and respect.

DISSERTATION APPROVAL

The abstract and dissertation of Dawood Sulieman Abugharbieh for the Doctor of Philosophy in Systems Science: Business Administration were presented June 9, 2006, and accepted by the dissertation committee and the doctoral program.

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GLOSSARY

Business marketing: Business-to-Business Marketing.

CFA: Confirmatory Factor Analysis.

Conversion efficiency: Low emissions.

COO: Cost of Ownership.

Demanufacturability: Ease of disassembly of sub-components.

Ecological usefulness: Same as ecological utility.

Ecological utility: The user's belief, about a particular ecological product attribute, in terms of its ability to facilitate the valued-sated of ecologically sustainable development.

Ecologically sustainable: Having no, or minimized, impact on natural resources.

Ecology: Natural environment.

Environmental utility: Same as ecological utility above.

EFA: Exploratory Factor Analysis.

Greenhouse gas emissions: For example CO_2.

ICT: Integrated Circuits and Telecommunications. Used as the overall umbrella description of semiconductor devices.

Ideal-state: The state one aspires to achieve (i.e. ecologically sustainable development); the overarching objective. Also referred to as the ideal reference state or the valued-state.

Industrial marketing: Business-to-Business marketing where user and supplier companies are involved in manufacturing activities.

ITRS: International Technology Roadmap for Semiconductors

Latent customer need: A customer need that is not apparent to the customer or marketer.

Natural environment: Ecology.

Product packaging: Reduced energy and materials, recyclability, and reusability.

Remanufacturability: Ease of refurbishing for other applications or users.

ROI: Return On Investment.

SEM: Structural Equation Modeling.

Upgrade-ability: life-cycle extension.

Valued-state: Same as ideal-state.

Waste: Solid, liquid, or stack emissions.

CHAPTER 1

OVERVIEW OF THE RESEARCH

INTRODUCTION TO THE RESEARCH PROBLEM

Customer value, based on ecological product attributes, is widely viewed in the literature as a potential source of competitive advantage (Henion 1981; Hart 1995; Lawrence and Morell 1995; Porter and Linde 1995; Starik and Rands 1995; Banerjee, Iyer *et al.* 2003). However marketing research in this arena is dominated by single industry case studies with little empirical evidence of specific market requirements (Banerjee, Iyer *et al.* 2003). As a result the natural environment's unbiased, empirically demonstrated, role in building customer value remains a sparsely explored area.

This industrial marketing research is designed, in the context of the semiconductor manufacturing capital equipment industry, to explore the relationships between users' perceptions of ecological product attributes (i.e. beliefs), attitudes towards the natural environment (i.e. ecological concern), and their market behavior (i.e. adoption of new products) as a possible source of supplier competitive advantage. The source of such advantage is related to responsiveness to external change (Grant 2002); which is the emergence of ecological impact as a relevant constraint on industry expansion (Post and Altman 1994; Porter and Linde 1995; Prothero 1998), and the development of customer focused capabilities (Day 1994). The nature of potential competitive advantage is related to hypothesized gains in market share via increased possibility of new product adoption, enhanced customer-oriented marketing abilities by better understanding the needs of different market segments (Day 1994), as well as improved product engineering skills via joint research and development cooperation with users (Grant 2002).

The ability to reduce the ecological impact of a firm's products provides a potential for firms to gain competitive advantage (Hart 1995; Starik and Rands 1995). The 1990's saw the emergence of a strong interest in the study of the ecological impacts associated with the development and use of new products and services (Gladwin, Kennely *et al.* 1996). Although the potential for gaining competitive advantage based on ecological product characteristics might exist, there is little empirical marketing research in this area (Banerjee, Iyer *et al.* 2003).

Businesses in general have not fully characterized this trend due in part to the unfamiliar social aspect of its nature that needs to be considered along with the more familiar economic aspects (Bansal 2002). Furthermore, government regulations, which are the traditional means for addressing ecological concerns, may not provide the most efficient mechanisms for achieving the desired outcomes or basis for business opportunity (Porter and Linde 1995; Swanson 1999; Westkamper, Alting *et al.* 2001). However regulations influence cost and thus should be considered when examining customer perceptions.

Specifically for the semiconductor industry, the International Technology Roadmap for Semiconductors[1] (ITRS) identifies difficult technological challenges and needs facing the industry over the next 15 years. The reduction of the ecological impact has been identified as one of those challenges. The European Semiconductor Industry Association (ESIA), Japan Electronics and Information Technology Industries Association (JEITA), Korean Semiconductor Industry Association (KSIA), US Semiconductor Industry Association (SIA), and Taiwan Semiconductor Industry Association (TSIA) are all sponsors the ITRS. International SEMATECH[2] acts as the global communication center for this activity. In their words (SIA 2003):

> *The International Technology Roadmap for Semiconductors (ITRS)* is the result of a worldwide consensus building process. This document predicts the main trends in the semiconductor industry spanning across 15 years into the future. The participation of experts from Europe, Japan, Korea, and Taiwan as well as the U.S.A. ensures that the *ITRS* is a valid source of guidance for the semiconductor industry as we strive to extend the historical advancement of semiconductor technology and the worldwide integrated circuit (IC) market.

The theoretical framework of cognitive structure is used in this research to account for the fact that ecologically influenced decisions involve both economic and social aspects, which have not been thoroughly addressed in business markets (Bansal 2002). It allows for the inclusion of economic outcomes and importance aspects as well as social belief and attitude aspects

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[1] The International Technology Roadmap for Semiconductors (ITRS) is an assessment of the semiconductor technology requirements. This assessment, called roadmapping, is a cooperative effort of the global industry manufacturers and suppliers, government organizations, consortia, and universities. The ITRS will be discussed in further details in Chapters 1 and 2.

[2] SEMATECH is a global industry consortium for accelerating technology innovation in semiconductor manufacturing, setting global direction, and conducting strategic R&D. (source: sematech.org)

in the empirical exploration of relationships between ecological product attributes and market outcomes. The main market outcome is defined in terms of customers' intentions of pursuing (or not) the adoption of products with specific ecological attributes (Engel, Blackwell *et al.* 1986). Other market outcomes that are examined include cooperative customer relations in terms of their intention to pursue joint research and development of new production technology (Cannon and Perreault 1999), and improved marketing abilities in terms of achieving meaningful ecological segmentation (Grant 2002).

Utilizing the personal belief component in cognitive structure models requires a reference point of an ideal or valued state (Rosenberg 1956; Beckwith and Lehmann 1973). The valued state in this industry-specific research is the one held by the ITRS; which is continued expansion of semiconductor manufacturing with reduced impact on natural resources (SIA 2003). In addition, there is an economic importance aspect associated with belief and represents current Cost Of Ownership (COO) models, which are used by each customer to measure and compare the Return On Investment (ROI) for all alternative products under consideration for adoption in manufacturing operations.

To illustrate the difference, a customer may personally *believe* that reducing water usage is *very important* to achieving continued industry expansion with reduced impact on natural resources, but work in a region that has an abundance of water resources and therefore it is considered a *minor factor* in economic importance or COO analysis.

Ecological impact has long been mentioned as a relevant issue affecting economic growth. After a relative lull in the 1980s, concern about ecological degradation associated with economic development and industrial expansion has been reemerging as a potentially consequential customer-value construct (Fisk 1973; Kirkpatrick 1990; Bohlen, Schlegelmilch *et al.* 1993; Cordano and Frieze 2000; Eder 2001; Bansal 2002), thus generating several related research streams in marketing and business management literature.

These streams addressed the segmentation of socially conscious consumers (Anderson and Cunningham 1972), perceived ecological value (i.e. costs and benefits) of responsible consumption (Fisk 1973), social and ecological marketing (Henion 1981), potential gain of competitive advantage through ecologically driven customer benefits (Porter and Linde 1995), the paradigm shift nature of ecological sustainability and relevant management actions (Gladwin, Kennely *et al.* 1995; Hart 1995), tensions between what companies could and should do to address rising ecological concern (Swanson 1999), and the difficulties companies face when formulating a response to ecological opportunities (Bansal 2002).

There is an empirical research void in addressing the link between potentially beneficial market outcomes and product attribute benefits in relation to the natural environment, likely due to the unique complexity of the social nature of ecological sustainability, to which most businesses do not yet know how to respond (Bansal 2002); arguably some businesses may not have attempted a response due to their objective or subjective assessment that economic benefits from such response would not justify the resources needed.

In an effort to examine both social and economic aspects affecting product adoption decisions and other beneficial outcomes, this research posits and empirically tests a model of ecological belief, ecological concern, and their relationship with customer intentions as illustrated in Figure 1. Analogous models based on attitude theory have demonstrated the ability to measure and characterize socioeconomic constructs (Kinnear, Taylor *et al.* 1974; Lounsbury and Tornatzky 1977; Bohlen, Schlegelmilch *et al.* 1993).

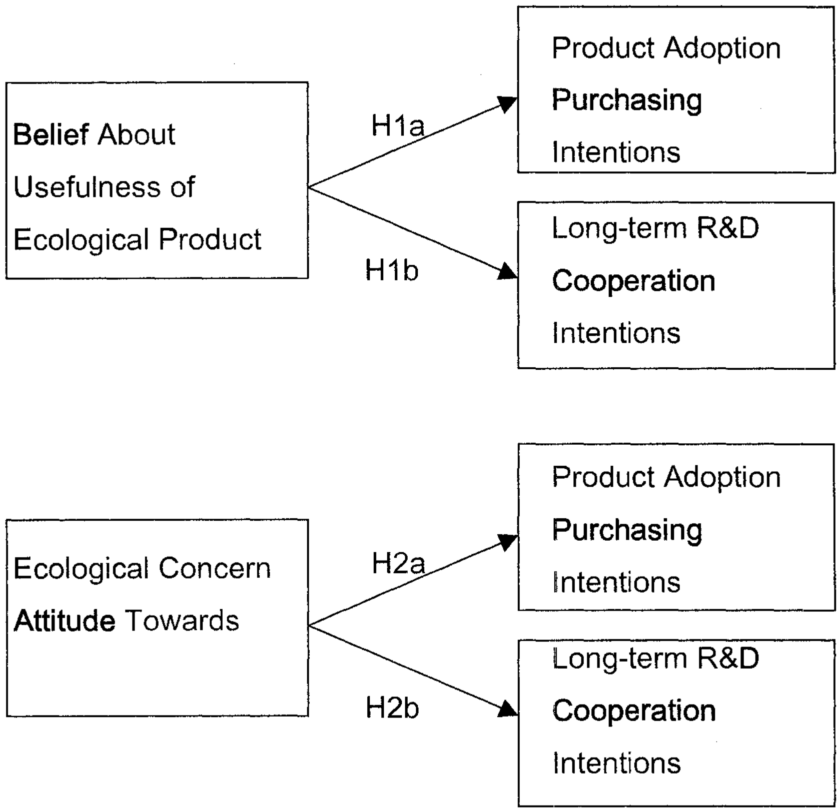

Figure 1: Conceptual Model of Research Relationships

In business markets that are sufficiently complex to warrant a formal decision making process, the adoption of new products based on specific product attributes, or other value drivers, encompasses an evaluation phase that buyers undergo before they reach a purchasing decision (Engel, Blackwell *et al.* 1986). Such an evaluation includes the formation of user beliefs and attitudes, which have been demonstrated to predict purchasing behavioral intentions of potential users in both consumer (Fishbein 1967) and capital equipment (Wildt and Bruno 1974) markets. Following a formal decision making procedure is also the case in the semiconductor industry, where users' new manufacturing process development invariably involves side-by-side trial evaluations of various products. Hence the relevant beneficial market outcome (or purchasing intention) is inclusion of a supplier's new product in trial evaluations (Engel, Blackwell *et al.* 1986; Berglund 2005); if a product is not included in the trial evaluations it has no chance of being adopted.

Similar to other market research, a conceptual investigation involving relevant attitudes and beliefs is only the first step in the marketing management process, and is utilized as the scientific basis for subsequent scale development, segmentation, and other marketing activities (Kotler 1999). The marketing concept's main contention is that organizational success is related to the relative effectiveness and efficiency of a firm in identifying and satisfying the expressed and latent needs of target markets (Kotler 2003; Narver, Slater *et al.* 2004).

The business objectives of this study are to understand how latent user beliefs about the usefulness of ecological product attributes and their attitude towards the environment, expressed in the form of ecological concern, are related to their purchasing and relationship forming intentions (market outcomes), as well as to evaluate the effectiveness of market segmentation schemes based on expressed perceptions of economic importance of such attributes.

RESEARCH PROBLEM

Early marketing research addressing concepts related to the natural environment was successful in finding the ecological concern dimension (Kinnear and Taylor 1973), profiling “green” customers (Kinnear, Taylor *et al.* 1974), determining their predictability as a niche segment (Anderson and Cunningham 1972), and measuring benefits of responsible consumption (Antil and Bennet 1979) by using operational definitions like “ecological concern”, “environmental concern”, and “social consciousness” as attitude related measures. Although there is a shortage of empirical studies on the subject of how ecological concern relates to market performance, there is a large body of work that presents it as a potential source of competitive advantage as cited in the previous Overview section.

As ecological marketing research expanded, attitude theory based on customer beliefs was introduced to examine customer motivations, attitudes, and behaviors for the purpose of segmentation along ecological dimensions (Bohlen, Schlegelmilch *et al.* 1993). Other research explored new product development activities using ecological design constraints (Polonsky and Ottman 1998). In general, ecological marketing research remained focused on seeking competitive advantage by searching for environmentally sensitive consumer niches as opposed to industrial business-to-business marketing applications (Kilbourne and Beckman 1998; Chen 2001). This despite the fact attitude theory’s cognitive structure provides a suitable framework for industrial as well as consumer marketing research (LaPlaca 1997; Kilbourne and Beckman 1998). In such models, objects around which beliefs are formed need not be limited, as they have been, to brands or services, they can also take the form of concepts and product attributes as long as an ideal reference state exists to anchor the expression of belief (Rosenberg 1956).

Recent business case study research emerged with a focus on the assessment of the ecological attributes of a product, which are conceptualized as quantitative ecological impact indicators, and ecological consequences of a product throughout its lifespan. Table 1 provides a list of such attributes and each one is defined in the Literature Review chapter. As one might expect, attributes used in different studies and their specific definitions vary depending on the context and scope of each study (Lendaris 1986; Flannery and May 2000). So far in this research stream, assessments are mostly focused on cost benefits such as reducing regulatory compliance cost and end-of-pipe waste management (Feldmann, Meedt *et al.* 1999; Chen 2001; Westkamper, Niemann *et al.* 2001).

Ecological Product Attribute	**Citation**
Energy Requirements (maybe also energy required to actually make the equipment at the supplier)	(SIA 2003), (Henion 1981) (Janssen and Jager 2002) (Feldmann, Meedt *et al.* 1999), (Gladwin, Kennely *et al.* 1995) (Westkamper, Alting *et al.* 2001)
Water Consumption	(SIA 2003), (Feldmann, Meedt *et al.* 1999)
Mass	(Feldmann, Meedt *et al.* 1999), (Zhang, Wang *et al.* 1999)
Number of Hazardous Materials Involved	(SIA 2003), (Janssen and Jager 2002), (Feldmann, Meedt *et al.* 1999) (Zhang, Wang *et al.* 1999)
Toxicity of Material Involved	(SIA 2003), (Janssen and Jager 2002), (Feldmann, Meedt *et al.* 1999) (Starik and Rands 1995), (Antil, 1979), (Westkamper, Alting *et al.* 2001)
Conversion Efficiency (Emissions Reduction)	(SIA 2003), (Gladwin, Kennely *et al.* 1995) (Starik and Rands 1995) (Westkamper, Alting *et al.* 2001)
Recycled Content	(SIA 2003), (Janssen and Jager 2002), (Feldmann, Meedt *et al.* 1999), (Gladwin, Kennely *et al.* 1995), Antil 1979
Recyclability (profits)	(SIA 2003), (Feldmann, Meedt *et al.* 1999), (Gladwin, Kennely *et al.* 1995) (Starik and Rands 1995), (Antil, 1979), (Westkamper, Alting *et al.* 2001)
Green House Gases (i.e. CO2)	(SIA 2003), Westkamper, Alting *et al.* 2001
Demanufacturability (time for disassembly or dismantling)	(SIA 2003), (Janssen and Jager 2002), (Feldmann, Meedt *et al.* 1999) (Zhang, Wang *et al.* 1999) (Gladwin, Kennely *et al.* 1995) (Westkamper, Alting *et al.* 2001)
Remanufacturability	(SIA 2003), Westkamper, Alting *et al.* 2001
Regulatory Compliance Cost	(SIA 2003), (Feldmann, Meedt *et al.* 1999) (Zhang, Wang *et al.* 1999)
Disposal Cost	(SIA 2003), (Janssen and Jager 2002), (Cordano 2000) (Feldmann, Meedt *et al.* 1999) (Starik and Rands 1995)

Table 1: Ecological Product Attributes (Prior to Panel Input)

The mechanism of assessing ecological consequences is presented as a quantification of a product's (or process') physical impact on the environment (Feldmann, Meedt *et al.* 1999; Eder 2001; Janssen and Jager 2002), which is defined as the sum of ecological indicators or attributes such as the amount energy required, water needed, nature of materials used, recyclability, disposal cost, and other relevant attributes similar to the ones listed in Table 1.

In industrial markets, a product's attributes that provide substantial customer benefits or lead to cooperative buyer-seller relationships have considerable customer value significance (Cannon and Perreault 1999; Lapierre 2000). As such, the future value offering (e.g. product attributes) determination process, used to guide product development, should be customer driven to increase the potential of favorable market outcomes (Woodruff 1997).

The primary purpose of this research is to analyze the relationship between ecological product attributes and users' purchasing intentions. The study has three major objectives: (1) to develop a valid measure of the construct representing users' belief structure about ecological attributes; (2) to define in this industrial marketing context the attitude construct of ecological concern; and (3) to examine the empirical relationships between beliefs and attitudes and market outcomes. Other objectives include the assessment of the relationship between belief and attitude, examination of the utility of using the economic importance of ecological product attributes as the basis for customer segmentation, and its role in improving ecological belief's ability to predict customer intentions. The research takes place in an industrial manufacturing business-to-business context, specifically with front-end[3] capital process equipment producers as the suppliers for the semiconductor manufacturing industry users.

Through the ITRS, users have identified their ecological impact as an area of difficult long-term challenges (SIA 2003). Ecological product attributes listed in Table 1 are used as belief measurement scale items in this research and are derived from the ITRS list of relevant ecological variables, which is aligned with ecological indicators in the product life span assessment literature mentioned earlier. In the semiconductor industry efforts to approach ecologically sustainable development, the stated goal of the ITRS is "continued expansion of semiconductor manufacturing with reduced impact on the natural environment"; in a cognitive structure based model, this stated goal is referred to as the "valued-state" or "ideal-state".

In this study's industrial marketing context, the potential for gaining competitive advantage is defined in terms of achieving favorable market outcomes. The primary such outcome is supplier selection for trial testing stage by the users which is illustrated in the decision framework of the Industrial Adoption Process Model shown in Figure 2 (Engel, Blackwell *et al.* 1986). The evaluation stage involves the examination of beliefs and attitudes that are hypothesized to predict user selection intentions for trial testing.

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[3] Front-end processing refers to fabrication of integrated circuits on entire (whole) silicon wafers as opposed to back-end processing which refers to the packaging of fabricated integrated circuits after the dissection of the silicon wafers into individual chips.

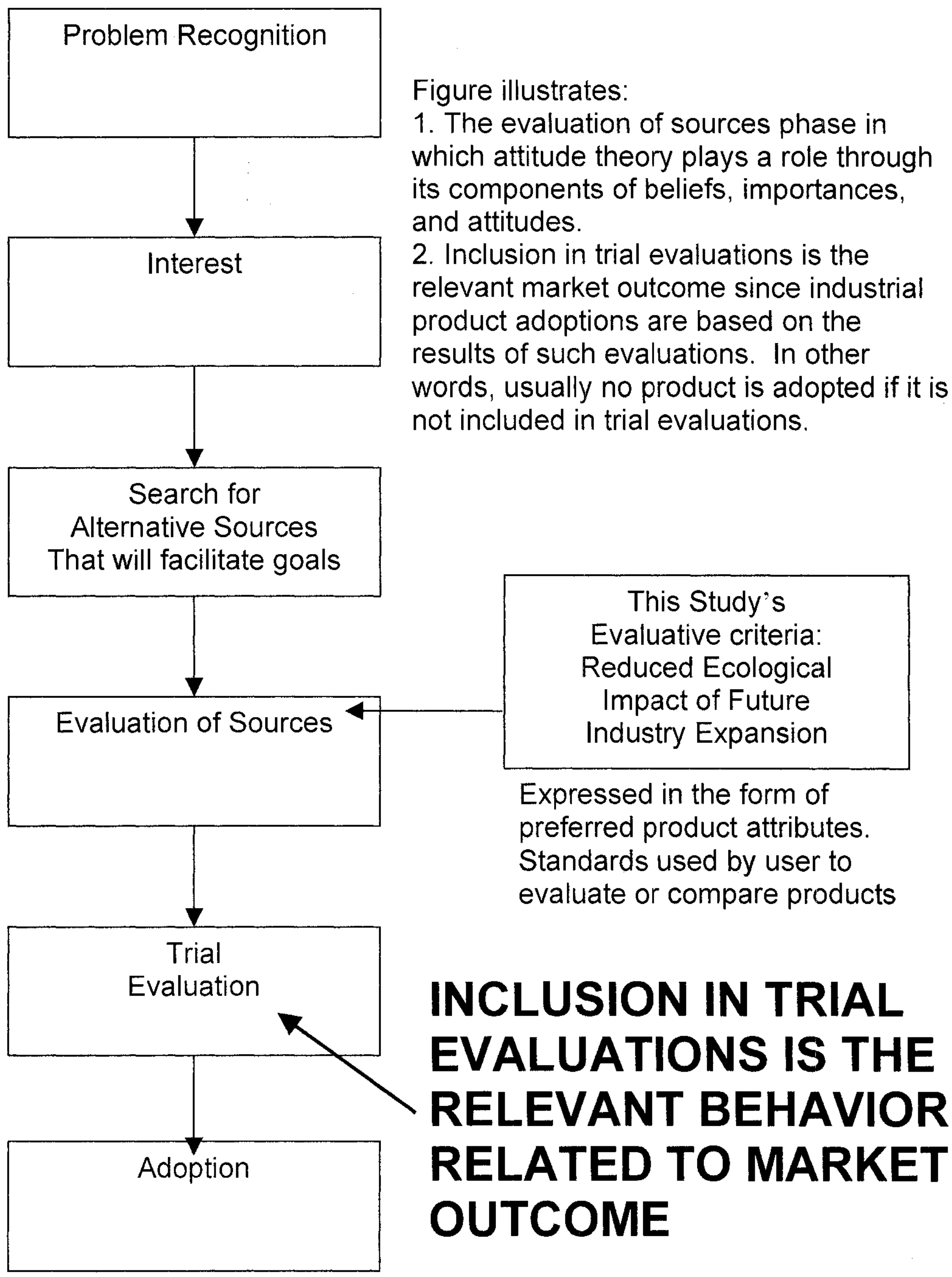

Figure 2: The Industrial Adoption/Purchase Decision Process Model (adopted from Engel et.al 1986)

This research adds to extant business marketing research by extending the application of cognitive structure theory to measure beliefs about ecological product attributes, quantify attitudes towards the ecological impact in an industry, and determine how they are related to purchasing intentions of semiconductor process equipment customers (Wildt and Bruno 1974). This study differs from the few analogous studies (Scott and Bennett 1971; Wildt and Bruno 1974) in that it does not use generalized product performance attributes (i.e. quality), rather it is focused on ecological impact related attributes. Performance attributes are not ignored; rather they are assumed to be adequate not to stop a product from being included in a trial evaluation.

All attributes (performance, ecological, or others) are considered in users' COO models, and this study posits that one can use the perceptions of attribute economic importances to represent customer assumptions of how each attribute is related to their ROI. The economic importance of attributes is used to segment the market so that belief and intention relationships are tested for each segment individually (Scott and Bennett 1971). This amounts to applying a modified version of Rosenberg's two factor linear attitude model (Rosenberg 1956) to business marketing that is specifically concerned with ecological (socioeconomic) variables in an industrial capital equipment context.

This research also includes an independent variable that represents knowledge about ecological issues, since such knowledge is thought to influence attitude development (Bohlen, Schlegelmilch *et al.* 1993). The two main dependent behavioral intention variables are 1) stated intentions to include a supplier in the trial testing stage and 2) intentions to enter into cooperative seller-buyer joint research and development.

Although the second behavioral intention is not formally part of the industrial adoption process illustrated in Figure 2 above, its examination is warranted in light of the long-term ITRS time horizon spanning 15 years (SIA 2003) and its potential to facilitate gaining competitive advantage (Cannon and Perreault 1999; Grant 2002).

RESEARCH DIRECTION

The main business objective of this research is to examine how belief about ecological attributes of products and attitudes towards the environment are related to product adoption intentions in semiconductor manufacturing. Context-specific measures of users' beliefs and attitudes are developed and assessed in terms of their predictive ability with respect to customers' purchasing intentions. Economic importance of the same ecological attributes used to form the belief measure is included as a segmentation variable, and since meaningful segments were found, it was used to improve the predictive ability of belief.

When issues with social aspects are considered in marketing, a balance must be found between company profits, customer needs, and public interest (Kotler 2003). In essence expanding the marketing concept's emphasis on satisfying target market needs to also encompass socially oriented needs while the company maintains a disciplined approach to ROI. These three considerations along with the ecology can be conceptualized as ends of a modified marketing pyramid as suggested by Parasuraman (Parasuraman 2000) and shown in Figure 3, which supports the theoretical basis of the appropriateness of developing a customer-ecology link.

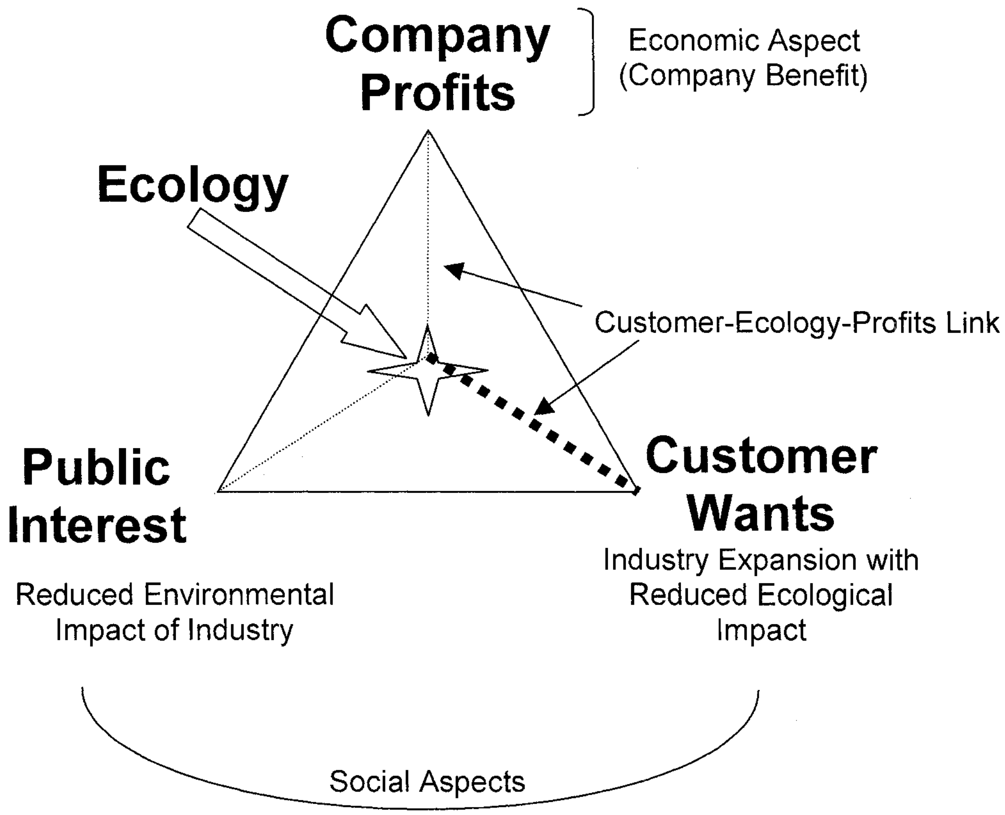

Figure 3: Pyramid Marketing Model
(adapted from Parasuraman 2000 and modified to reflect Kotler 2003 triangle of balance in societal marketing)

Cognitive structure and attitude theory have been demonstrated as a suitable framework for examining socioeconomic issues such as ecological concern (Sheth 1973; Kinnear, Taylor *et al.* 1974; Lounsbury and Tornatzky 1977). Measures of ecological concern (attitude) and their relation to behavior have been examined in various consumer contexts, however this study differs in its business market context, and its goal of addressing the practical need for industry to maintain a market-based discipline while addressing ecological issues. Hence, to enable supplier firms to be *proactively* market-oriented a measure is constructed based on customer beliefs towards ecological product attributes quantifies latent needs (Narver, Slater *et al.* 2004), and those needs are assessed in terms of their ability to predict market outcomes.

Investigating how users' beliefs (about the natural environment) influence a company's commercial performance is intended to partially fill the current void in empirical evidence of specific ecological market requirements (Banerjee, Iyer *et al.* 2003), with the added distinction between expressed and latent needs (Narver, Slater *et al.* 2004). Learning about customer ecological beliefs, attitudes and intentions (i.e. market learning) enables suppliers to increase customer-value; such outward market orientation has been shown to provide potential gain of competitive advantage (Slater 1997; Woodruff 1997).

A recent study has shown that proactive market orientation that attempts to address latent customer wants (wants they don't yet recognize), is a more effective approach to market orientation than responding only to expressed customer needs (Narver, Slater *et al.* 2004).

Ecological impact issues have been demonstrated to be an important customer-value dimension worthy of empirical investigation (Porter and Linde 1995; Bansal 2002). The increasing relevance of ecological variables in marketing and business decisions is not a fad (Prothero 1998), and the need to examine the consequences of corporate environmentalism has been empirically demonstrated (Banerjee, Iyer *et al.* 2003). However, even in the much explored consumer markets, there is a shortage of empirical marketing research of ecologically oriented product attribute segmentation variables, attitudes towards the natural environment, and the nature of ecologically related behavior (Bohlen, Schlegelmilch *et al.* 1993). Furthermore, journals of industrial marketing[4] research are all but void of research efforts to explore ecological concern in a business-to-business environment, however they have explored industrial purchasing behavior and provide useful business-to-business marketing frameworks to explore beliefs, attitudes, and values (LaPlaca 1997; Kilbourne and Beckman 1998).

This research empirically investigates the predictive ability of the belief and attitude components of linear attitude models (Fishbein and Ajzen 1975; Engel, Blackwell *et al.* 1986) in the context of the semiconductor capital equipment market, specifically determining how (or if) the beliefs associated

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[4] There are four prominent journals that have focused their publications on scholarly articles in business-to-business marketing topics. They are Industrial Marketing Management, Journal of Business and Industrial Marketing, Journal of Business-to-Business Marketing, and Advances in Business Marketing and Purchasing. Woodside, A. G. (1997). "Contributions of Business-to-Business Marketing Journals: Introduction to the Special Issue." Journal of Business Research **38**(3): 177.

with ecological product attributes predict users purchasing intentions in relevant segments and/or the total sample population.

Belief about the usefulness of ecological attributes and associated economic value importance are measured as perceptual responses to verbal statements. The attribute importance responses are examined to determine if differences exist between users' perceptions to avoid the risk of inference mistakes about which ecological attributes best predict behavior (Scott and Bennett 1971).

As a segmentation variable of the relationship between belief and behavior, importance represents the degree of economic value currently associated with each ecological product attribute. Although, as explained fully in the attitude theory section of the literature review, researchers differ on whether attribute importance adds to or subtracts from predictive ability of attitude models, it is included for 2 reasons: (1) it represents economic assumptions associated with each attribute which by itself would provide valuable insight into users expressed needs; and (2) it is not known *a priori* if differences exist between customers' perceptions in this specific industry context; whenever customers can be segmented on the basis of value importance then belief and intention relationships must be examined separately for each segment (Scott and Bennett 1971).

As operationalized in the methodology chapter, objects to which beliefs and importance perceptions apply are represented by product ecological attributes listed in Table 1 and ones suggested by a multi-perspective panel also discussed in the methodology and analysis chapters. The valued-state is defined in line with the ITRS definition. Beliefs about product attributes, perceptions of attribute importances, ecological concern, knowledge about ecological issues, and market outcomes related to behavioral intentions are measured using the questionnaire survey instrument in Appendix A.

Beliefs about the ability of each product attribute to facilitate industry expansion with reduced impact on natural resources are measurable independent variables that are asserted, along with ecological concern attitudes, to be related to behavioral intentions (Fishbein and Ajzen 1975; Engel, Blackwell *et al.* 1986; Flannery and May 2000).

As a way to account for both social and economic aspects of the environmental impact of the industry, each ecological product attribute is associated with two measurements: (1) The degree users believe it helps in expanding the industry while minimizing its impact on the natural environment; and (2) The economic importance of that attribute (Rosenberg 1956; Fishbein 1967; Scott and Bennett 1971). The primary market outcome variable of behavioral intention is operationalized using verbal statements concerning the users' intention to include ecological attributes in the selection criteria for upcoming new product trial evaluations (Fishbein and Ajzen 1975; Engel, Blackwell *et al.* 1986). The ability to discover a meaningful segmentation scheme on the basis of ecological product attributes also provides valuable market learning insights.

Ecological concern is measured based on responses to statements derived from the relevant literature and are further explained in Chapter 2 along with all other relevant variables. Two additional variables are measured for exploratory purposes.

First, the extent of the users knowledge about specific ecological issues, such knowledge is frequently hypothesized to influence attitude (Scott and Bennett 1971; Lounsbury and Tornatzky 1977; Henion 1981). It is important, in the context of measuring ecological dimensions, that the respondents understanding of the consequences of their behavior on the natural environment is assessed (Bohlen, Schlegelmilch *et al.* 1993). Table 2 lists the knowledge scale items and their sources, additional items were added by the research panel and include in the survey illustrated in Appendix A.

Second, users are asked to indicate their long-term cooperative intentions of seeking out equipment suppliers for joint research and development to reduce the ecological impact of their next generation processing technology. This measure of long-term intentions is a relevant market outcome (Cannon and Perreault 1999), and is useful in light of the ITRS 15 year time horizon.

Knowledge Indicators	Citation
Greenhouse gases	SIA 2003
Acid Rain	Bohlen 1993
Sea/river pollution	Antil 1979, Bohlen 1993, Lounsbury 1977, SIA 2003
Air pollution	Antil 1979, Bohlen 1993, SIA 2003
Global Warming (climate change)	Bohlen 1993, SIA 2003
Ozone layer depletion	Bohlen 1993, SIA 2003
Drinking water pollution	Antil 1979, Bohlen 1993
Pollution from pesticides/insecticides	Antil 1979, Bohlen 1993
Resource conservation	Bohlen 1993, Henion 1981, Antil 1979, Lounsbury 1977, SIA 2003, Cordano 2000
Radiation from storage of nuclear waste	Bohlen 1993
Full environmental cost accounting	(Starik and Rands 1995)
World population growth	Lounsbury 1977, Westkamper, Alting *et al.* 2001

Table 2: Items Related to Ecological Knowledge (Prior to Panel Input)

The respondents' perception of the extent of their regulatory environment is also measured. Although most semiconductor manufacturers operate in multiple geographical locations, this variable has the potential to impact their perception of product attributes cost importance and is therefore included as a possible determinant of economic importance.

Several other variables are included to help interpret results such as the size of the firm, respondent education level, and other demographic variables illustrated in the methodology chapter. These variables also help to understand differences between segments generated on the basis of perceptions of attributes' economic importance.

STUDY JUSTIFICATION AND SIGNIFICANCE

This research provides capital equipment suppliers in the semiconductor industry a better understanding of how their customer base views the issue of reducing the ecological impact of future industry expansions. Purposefully examining a specific industry is appropriate since each industry has its own unique ecological issues and concerns (Flannery and May 2000). Measuring the association between customers' beliefs regarding the usefulness of specific ecological product attributes and purchasing decisions illustrates how reducing the ecological impacts of their products can affect their business. In examining such relationships, suppliers can also assess future joint development opportunities with their customers.

The study also illustrates a semiconductor manufacturer segmentation scheme on the basis of their perceptions of ecological product attribute economic importance, which serves as a proxy for the attributes' economic relevance in existing COO models and may also be used along with belief scores as a product design guidance tool.

The resulting segmentation enables more effective marketing strategies that exploit company strengths when evaluating new product development opportunities (Engel, Blackwell *et al.* 1986), or to better position offerings against competitors. The study illustrates a method for utilizing new external opportunities, based on the increased relevance of ecological impact business considerations, to seek favorable market outcomes and improve competitive positioning, both of which are essential to marketing strategy (Grant 2002).

Opportunities related to ecological concerns exist based on both (a) general emerging preferences in industrial development (Bohlen, Schlegelmilch *et al.* 1993; Prothero 1998; Sharma 2000) and (b) specific users identification, through the ITRS, of reducing ecological impact as a relevant, and difficult, long term challenge for the semiconductor industry (SIA 2003). To benefit from such opportunities it is important to understand what ecological attributes are relevant and how they can aid in the trial evaluation selection phase of the industrial purchasing process shown in Figure 2. This research also incorporates an economic aspect to account for current decision-making criteria.

Economic cost importance of ecological attributes is used to find homogenous subsets of the presumably heterogeneous semiconductor manufacturers market. Varying segments can be targeted with specific ecological attribute offerings. Segmentation is a key element of marketing management, where segmentation variables are specific to the product class rather than having a universal nature regardless of their sophistication (Scott and Bennett 1971; Bass and Wilkie 1973; Engel, Blackwell *et al.* 1986). Therefore it is appropriate in this study to select independent variables (i.e. attributes) based on the specific industrial context and the relevant industry roadmaps. The segmentations attributes selected are identical to those typically used to measure beliefs.

This research adapts cognitive response theory (discussed in detail in Chapter 2) to accommodate physically measurable product attributes and differentiate beliefs as latent needs from perceived importances which are the expressed economic needs of target customers that might influence belief's relationship with behavior. This is done to address both the subjective social aspect of ecological issues facing semiconductor industry expansion, and the economically based aspects of ROI models such as commonly used COO models (Narver, Slater *et al.* 2004).

Consistency theories (such as cognitive response) are used to understand how customers decide to purchase and how marketers can influence this decision process through attitude change efforts and targeted marketing strategies. It is held that attitude learning and attitude change can be studied by an investigation of the structural relationships between attitudes and beliefs about attitude objects (Scott and Bennett 1971). This research also examines the influence of external variables that might affect the measures used in this study including a respondent's preexisting ecological knowledge and its effect on ecological concern attitude, and the current applicable regulations which may affect perceptions of economic importance (Belk 1975).

This study is timely and well positioned to take advantage of the current high level of deliberation to speed adoption rates of products designed to reduce ecological impact, and understanding particular market characteristics as a critical factor affecting those new products adoption rates (Janssen and

Jager 2002). Since semiconductor manufacturers are receptive as evidenced by their having already expressed interest in this area through the ITRS, studies of their particular market characteristics are justified (Lawrence and Morell 1995).

The following chapter provides a review of relevant literature, specific research questions, and related hypotheses. In general, this research is guided by the following question: to what extents do beliefs about ecological product attributes and ecological concern predict purchasing behavior in the semiconductor manufacturing industry? Addressing this question involves an investigation of customer beliefs about the ecological utility of product attributes, the role of attribute economic importance as a potential customer segmentation dimension, the ecological concern representing customer attitudes, and customer intentions.

ORGANIZATION OF DISSERTATION

The first chapter presented an overview of the research and its industrial marketing context – the relationship between users' beliefs and attitudes regarding the natural environment and their purchasing intentions in the semiconductor front-end processing equipment industry. It also provided an explanation of the background, relevance of this research, an illustration of the framework extending linear attitude models to specific prediction of customer behavioral intentions based on ecological attributes of products, and related marketing implications.

Chapter 2 provides a review of the relevant literature related to the topics pertinent to this study. This includes addressing users' ecological concern as a potential source of opportunity to gain competitive advantage, ecological product attributes as the relevant measurement items in this research, and attitude theory that is used as the framework for finding predictive relationships. Hypotheses based on the literature and used to address the research questions are subsequently presented.

Chapter 3 describes the methodology used in this research. This includes sampling, construct development, research design, research variables, procedures that guide the investigation, and the analyses plan to examine the stated hypotheses.

Chapter 4 presents results of the analysis and the role of a multi-perspective panel in improving the research measurement instrument, including input from industry, community, government, and academia, as well as the assistance from industry associations in subject recruitment. Also, data collection and characterization is explained along with details of the various statistical analyses used in hypotheses testing.

Chapter 5 provides a summary of the study, its major findings, relevant observations, contribution to marketing theory, and managerial implications based on the research results. Limitations are also explained along with ways to address them in future research.

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter includes a discussion of attitude theory and its role as a framework for the relations between belief structure, attitude measures, and purchase intentions in a business-to-business context. In addition, the chapter presents a review of the literature used to conceptualize and propose how cognitive structure is related to ecological product attributes and list those attributes that make up the objects associated with beliefs. Conceptualization of the ecological concern construct and the relevant market outcomes is also discussed. Ecological product attributes that affect its ecological footprint are presented and explained as well as the purpose behind using their economic importances as segmentation variables. Specific research questions and hypotheses are presented at the end of the chapter.

Since testing the proposed hypotheses is dependent on developing reliable and valid scales, Churchill's (Churchill 1979) widely used guidelines (Bohlen, Schlegelmilch *et al.* 1993; Parasuraman 2000) for conceptualizing marketing research measures are used as a guide for both belief and attitude (i.e. ecological concern) constructs. The process begins with consulting the relevant literature in order to specify a construct's domain, followed by a generation of a sample of items that capture the specified domain, and an empirical purification of the measures.

ATTITUDE THEORY

Building on social psychology research by Rosenberg (1956) and others, Fishbein articulated enduring definitions of attitudes and beliefs (Fishbein 1967), where he also illustrated the usefulness of using both phenomena within the framework of behavior theory as predictors of behavior or behavioral intentions. The theoretical foundations of attitude theory are found in the branch of social psychology that is concerned with structural relationships between attitudes and beliefs about objects, where these objects can be physical objects, brands, individuals, concepts, groups, political groups, or commercial products (Rosenberg 1956), and the term "concept" can refer to any distinguishable aspect of a person's world (Fishbein 1967).

The nature of attitude being a "learned" phenomenon provides theoretical support to the inclusion of knowledge as a relevant variable that potentially influences attitude. The relationships between belief, attitude, and behavioral intentions have been initially conceptualized by early psychology research in the early parts of the 20th century, synthesized by Rosenberg in the 1950's, explored in details by Fishbein in the 1960's and 1970's, and extended in a consumer-marketing context by Engel in the 1980's. The main contention of the theory is that measures of belief, attitude, and behavior are directly related and in the absence of the external influence of other variables the constructs can be considered equal alternative representations of a person's attitude; it is considered a stable theoretical framework for investigating those relationships (Fishbein 1967; Fishbein and Ajzen 1975; Engel, Blackwell *et al.* 1986). The belief component relates to causes and implications, attitude relates to feelings (e.g. pro-con) towards an object or concept, and the behavioral component represents conviction in what if anything should be done. Consequently, the conception of attitude should be multi-dimensional since any one individual's attitude may fall at three different positions on three different dimensions (Fishbein 1967).

The fact that attitude can be represented as a unidimensional variable does not mean a researcher should ignore beliefs and behavioral intentions, the objective should be to simultaneously investigate attitudes, beliefs, and behavioral intentions (Fishbein 1967). In this research belief is quantified using a proposed scale based on ecological product attributes, attitude is assessed based on a proposed ecological concern scale, and behavioral intentions is measured through verbal statements about intentions of supplier inclusion in trial evaluations and cooperating in joint technology development with suppliers.

Behavior is measured through the proxy of intentions because purchasing in the business context of this research has to follow strict procurement procedures when important capital acquisitions are considered, and mid to long-term intentions are more representative reflections of the relevant behavioral aspects of decision-making. The following two sections will explain how attitude theory is used in business marketing

Attitude theory, derived from the cognitive structure of beliefs about objects or concepts and attitudes, has long been applied in marketing research to explore socioeconomic oriented dimensions (such as ecological concern) in order to or predict buying behavior (Sheth 1973; Kinnear, Taylor *et al.* 1974; Lounsbury and Tornatzky 1977). Its use in this research is appropriate since challenges in addressing the industry's ability to respond to ecological issues largely stem from the fact such issues are socioeconomic in nature (Bansal 2002).

An additional utility for marketing is derived from the concept that the process of attitude learning and attitude change can be studied by an investigation of the structural relationships between attitudes and beliefs (Rosenberg 1956; Albert 1971).

COGNITIVE STRUCTURE

The cognitive structure of beliefs and attitudes is highly correlated with behavioral intentions, making it an effective predictor of purchasing intentions (Fishbein and Ajzen 1975; Flannery and May 2000), which in this research is mainly defined as selecting suppliers for trial evaluations. Cognitive structure has its roots in social psychology and is therefore able to accommodate the social aspects of the business goals at hand, making it a suitable framework for exploring the socioeconomic nature associated with ecological impact issues (Sheth 1973; Kinnear, Taylor *et al.* 1974; Lounsbury and Tornatzky 1977).

The underlying socioeconomic nature can be presented in the sense that beliefs about nature have a social aspect, whereas the business evaluations of product attributes for purchasing purposes are economic. Cognitive response (consistency) theory contends that initial beliefs and attitudes are important determinants of persuasion, and marketing researchers have applied such social psychology theories of consistency (also referred to as balance, congruity, symmetry, dissonance, and expectancy theories) in their quest to transform customer cognition of a product's offering to predict purchasing intentions (Scott and Bennett 1971). Such research took place in numerous contexts such as consumer markets (Bass and Talarzyk 1969; Bass and Wilkie 1973; Sheth 1973), capital equipment markets (Wildt and Bruno 1974), advertising source credibility effectiveness in varying buying situations

(Harmon and Coney 1982), and to assess attitudes towards ecological quality (Lounsbury and Tornatzky 1977). The varying applications, adaptations, and extensions of consistency theory are enabled by the universal nature and predictive ability, which is derived from of its contention that inconsistencies in a person's cognitive structure regarding his beliefs, attitudes, and behavior is a psychologically uncomfortable state which results in pressures to eliminate or reduce the inconsistency (Rosenberg 1956; Scott and Bennett 1971).

Cognitive structure is able to include both social aspects by considering personal beliefs and attitudes towards ecological objects and ecological concern, as well as economic aspects by considering intended customer behavior which is consequential to company profits (Sheth 1973; Kinnear, Taylor *et al.* 1974; Lounsbury and Tornatzky 1977), and the relevance of the economic importance perception of each belief object as the basis of market segmentation.

BUSINESS CONTEXT

As illustrated in the decision process model depicted in Figure 2, there is an evaluative sub-process that industrial firms undergo as they select which new products to include in trial testing prior to final adoption (Engel, Blackwell *et al.* 1986). This research assumes *a priori* that the problem recognition and interest phases in Figure 2 have taken place due to the following reasons: (1) the relevance of reducing ecological impact of industrial production has been recognized (Fisk 1973; Bohlen, Schlegelmilch *et al.* 1993; Prothero 1998; Bansal 2002) and presents as an opportunity to gain competitive advantage (Hart 1995; Porter and Linde 1995); and (2) specifically in the semiconductor manufacturing context the collective industry has formally expressed interest in pursuing its expansion while reducing its impact on natural resources (SIA 2003); this was accomplished by explicitly including this interest in its long-term roadmap that identifies ecological impact as an important and difficult industry-wide challenge.

The subsequent industrial adoption process phases involve the search for and evaluation of sources that will enable firms to accomplish industry-wide goals (Engel, Blackwell *et al.* 1986). This process of evaluating alternatives is grounded in attitude theory, where an evaluative criteria or a reference ideal-state, such as ecologically benign manufacturing (Helms 1997), is used to create belief perceptions about certain objects' (i.e. product attributes) usefulness in achieving the ideal-state. Those beliefs along with attitudes about the subject are hypothesized to predict subsequent product trial selection intentions (Fishbein 1967); a necessary step before product adoption.

All research on how ecological concern influences consumer behavior mentioned above uses the framework of attitude theory to find the association between attitude towards the natural environment and subsequent behavior. However, the framework is also suitable for exploring beliefs and attitudes of industrial customers as well (LaPlaca 1997; Kilbourne and Beckman 1998), although it is rarely used in such context and few marketing and management papers appear to have been published that empirically demonstrated such suitability (Wildt and Bruno 1974; Flannery and May 2000; Sharma 2000).

The paucity of attitude theory applications in industrial or business contexts represents a gap in marketing research. This is especially noticeable in efforts to gain a market-based competitive advantage from the ecological sustainability trend (Day 1994); confirming the view that the vast majority of companies have difficulties in responding to ecological challenges due to their dual social as well as economic aspects (Bansal 2002). Applying attitude theory has considerable utility since it has been repeatedly demonstrated by numerous studies to reliably approximate behavior (Engel, Blackwell *et al.* 1986).

In addition to intentions of including a product in trial evaluations on the basis of its ecologically related benefits, in an industrial context there is an important customer-supplier cooperative relationship aspect that should be assessed to better represent relations with customer value (Cannon and Perreault 1999; Lapierre 2000). Considering the fact that the SIA roadmap has a 15 year time horizon and the complex technology and process development that characterizes the semiconductor manufacturing industry, one could reasonably expect such firms to form partnerships with suppliers they perceive beneficial for joint technology development efforts (Grant 2002; SIA 2003). Hence a long-term customer-relations behavioral intention variable will be included as an outcome variable in this research.

ATTRIBUTE IMPORTANCE AS A SEGMENTATION VARIABLE

Researchers differ on the effect of value importance (i.e. attribute importance) on predictive ability of attitude models. In a study of consumer brand preferences ordering, attribute value importances were shown to add to the predictive ability of the cognitive structure model (Bass and Talarzyk 1969). This conclusion is consistent with asserted relevance of an "evaluative" aspect to be considered in conjunction with beliefs as presented by seminal researchers in social psychology (Rosenberg 1956; Fishbein 1967).

Several researchers that have evaluated the predictive ability of the general attitude model reached differing conclusions. An explicit evaluation of importances role found them unimportant in the sense they do not add to predictive ability (Beckwith and Lehmann 1973). The likely explanation provided was that "*individuals tend to spread their perceptions more on the attributes they consider to be more important*" (Beckwith and Lehmann 1973), thus value importances are only consequential when objective rather than subjective items are measured. Others demonstrated a lack of relevance of importance values (Churchill 1972) without providing much explanations of the logic behind the empirical results. One that utilized the linear attitude model in an industrial capital equipment context also reached the conclusion importances did not matter (Wildt and Bruno 1974).

An extensive study aimed squarely at quantifying the role of beliefs as a determinant of brand preference concluded that importance tend to suppress the predictive ability of the cognitive structure model (Sheth and Talarzyk 1972), and a subsequent study by one of the authors evaluated all possible ways of aggregation, summation, and disaggregation (10 ways in all) of belief and value importance reached the conclusion that beliefs alone produced better correlations with attitude and behavior (Sheth 1973).

The above studies about the role of value importance provided only anecdotal explanations of the reasons behind their empirical findings and did not provide practical business consequences of those findings. One empirical study that articulated the role of attribute importance and its business consequences demonstrated they are relevant only if differences exist in how customers perceived such importances, specifically if customers can be meaningfully segmented on the basis of their perceptions of product attributes importance (Scott and Bennett 1971). This finding is consistent with the view mentioned above that value importances are consequential when objective rather than subjective items are measured (Beckwith and Lehmann 1973). Product attributes that make up the belief objects in the research are relatively objective items and were formed as such; they were selected because they have a *measurable* physical impact on the environment.

Hence, in this research, after the list of product attributes has been finalized in a reliable and valid belief construct, the subsequent task was to quantify the differences that exist in customer importance perceptions of these attributes, and use them as segmentation variables of the semiconductor manufacturing market. The logic behind this approach is based on the fact that if one wishes to examine which attributes will differentiate customer segments that are likely to adopt the product from the ones that are not, one can not rely solely on direct ranking of the saliency or perceived instrumentality of the attributes, as that will only reveal their average importance (Scott and Bennett 1971); in their study Scott and Bennett also demonstrated the ability to use the importance of product attributes effectively as segmentation variable to improve belief's ability to predict behavior.

This research study differs from past studies in the sense that the value importance associated with each ecological product attribute will gauge that importance in the context of the attribute's assigned cost importance in the economic (COO) model used, thus giving its segmentation the additional power of being based on expressed customer economic needs (Narver, Slater *et al.* 2004). Therefore, in addition to assessing the utility of the belief component of cognitive structure in predicting purchasing intentions, its associated importance scores will be used as the basis of customer segmentation.

Finding consequential differences between various market segments has long been a staple of marketing research (Wiseman 1971; Day 1990). The identification and targeting of specific market segments is an integral part of any customer-value creation strategy, where the process aims at enabling firms to establish a position of competitive advantage through a unique customer value propositions (Day 1994; Slater 1997).

In consumer and industrial markets, benefit segmentation on the basis of product attributes sought by users, is an important concept (Scott and Bennett 1971; Bohlen, Schlegelmilch *et al.* 1993). Within the above segmentation and value creation context, marketers seeking favorable market outcomes regularly engage in determining not only what target customers value in the present, but also what target customers are likely to value in the future to guide new product development (Woodruff 1997; Lapierre 2000).

Ecological characteristics of products have been demonstrated as viable segmentation dimensions in the context of "socially responsible behavior" (Antil and Bennet 1979). However, as mentioned above, the common overarching goal was to identify individuals in consumer niche segments and their characteristics for specific targeting campaigns (Henion 1981; Kilbourne and Beckman 1998). Lower ecological impact of products was also presented as a relevant customer value benefit that serve as sound basis of segmentation in consumer markets (Anderson and Cunningham 1972; Kinnear and Taylor 1973; Kinnear, Taylor *et al.* 1974; Bohlen, Schlegelmilch *et al.* 1993) and business markets (Porter and Linde 1995).

In summary, when attitude models are applied in the context of predicting customer behavior, segmentation based on customers' perceptions of product attributes economic importance potentially plays a critical role in their ability to predict behavior. Segmentation based on ecological attribute economic importance also provides the marketer valuable insight that can be used to customize offerings that are responsive to expressed customer needs.

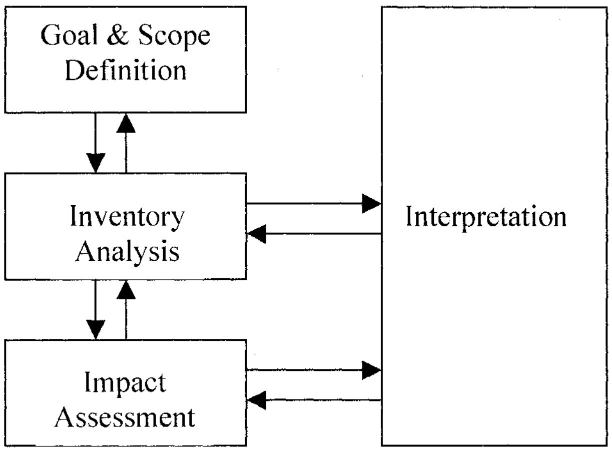
ECOLOGICAL FOOTPRINT PRODUCT ATTRIBUTES

"Products are defined in psychology field as bundles of attributes"

(Fishbein 1967)

In this study, ecological product attributes are used to solicit responses of personal beliefs about their ecological usefulness and perceived economic importance in current purchase decision models.

Over the past decade, and possibly due to a marked increase in importance of ecological degradation as a critical business issue (Kirkpatrick 1990), a stream of practitioner oriented papers emerged to address ecological consequences of industrial manufacturing. Such efforts are more detailed and context oriented than academic publications by virtue of the narrower focus of practitioner research objectives. For the most part, authors utilize the general framework of product life span assessment according to globally accepted ISO-14040 standards shown for illustration purposes only in Figure 4 (Kane, Stoyell *et al.* 2000; Westkamper, Alting *et al.* 2001). Kane and colleagues suggested an extension to the ISO-14040 model to account for subjective data quality that greatly influences the impact assessment phase and to make the process more dynamic, but this is beyond the scope of this research.



Goal and Scope: Where highest leverage exists
- Set system boundaries and
- Define Functional Unit

Inventory Analysis: Product attributes
- Material and energy flows

Impact Assessment: Data quality matters
- Environmental impacts of flows
- ISO 14000 extensions

Interpretation: Generate environmental "score"
- Classification (i.e. toxicity, half life)
- Characterization
- Normalization
- Weighting

Figure 4: ISO-14040 Life Cycle Assessment Framework

To address the expected difficulties associated with impact assessment calculations for complex products (semiconductor manufacturing equipment are considered extremely complex) sophisticated mathematical computer models are used for optimization of the design process in the Scope phase in Figure 4 based on end-of-life criteria (Chen 2001; Feldmann, Trautner *et al.* 2001). In addition, several researcher have applied popular marketing and product design techniques such as Quality Function Deployment (QFD) and conjoint analysis to evaluate ways of reducing ecological impact of manufacturing operations (Zhang, Wang *et al.* 1999; Chen 2001); such an approach could be used to extend this research after its completion.

Although automation of attribute assessment for design purposes is a necessary element for creating products with lower impact on the natural environment, the inclusion of customer perceived benefits value, critical in gaining competitive advantage in industrial markets (Lapierre 2000), is absent from such models.

To illustrate the importance of product attributes design (including ecological ones), they were proposed as the conduit to apply technical knowledge to Deign for Environment (DfE), Design for Manufacturability (DfM), and to design for product life extension and adaptability (Westkamper, Alting *et al.* 2001). This perspective illustrates the power of the design phase of product development in maximizing benefits in a direct manner, since all subsequent consequences are related to design phase decisions; few other papers addressed this phase specifically (Chen 2001).

The ecological impact of a product is determined through a comprehensive examination of its inventory of items that have ecological consequences, and calculating end-of-life metrics related to the inventory list, where the calculation formulas are based on how inventory items are classified (e.g. toxicity level), characterized, normalized, and weighted to generate a sort of "environmental scores" (Feldmann, Meedt *et al.* 1999).

Table 1 above provided a list of initial inventory items derived from the literature and semiconductor associations for the specific context of this research, those items fall into three general categories: natural resource consumption, impact on the natural environment, and costs associated with regulatory compliance and end-of-life (Henion 1981; Starik and Rands 1995; Westkamper, Niemann *et al.* 2001); that will be confirmed by the factor analysis presented later in this paper. Additional attribute items will also be added prior to the planned survey using input from a multi-perspective panel described in Chapter 4's Overview.

Specifically, in the semiconductor industry the relevant ecological attributes have been identified by the ITRS (SIA 2003) and they include: energy requirements, water consumption, number of hazardous materials involved in product use, toxicity of materials involved, conversion efficiency[5], recycled content of the actual product, demanufacturability, recyclability, regulatory compliance cost, and disposal cost. All those attributes were included in Table 1 along with other attributes suggested by the literature.

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[5] Conversion efficiency refers to the percentage of material used that remains in the final product as opposed to materials emitted as hazardous affluent. 100% conversion efficiency means zero emissions.

ECOLOGICAL FOOTPRINT PRODUCT ATTRIBUTE ITEMS

Following is an explanation of Table 1 items. For presentation purposes the citations will not be repeated. Also, items not in Table 1 that were added by the research panel are indicated.

Natural resource conservation:

- Energy: A common item in ecological assessments in both business and consumer markets due to its common association with the effects of burning fossil fuels, nuclear waste, or use of non-renewable resource. It is one of the "utility" items in the SEMATECH generic COO model template. It is easily measured and its cost is a simple calculation based on energy prices at each particular location. The objective is to minimize its required amount.
- Water: As common of a factor as energy and the large amount required for semiconductor factory operations has presented an expansion problem for several high profile manufacturers. It is the second utility item on the SEMATECH COO template, is easily measured, and the objective is to minimize its required amount.
- Mass: The total amount of material used in making the equipment. It is relevant in semiconductor manufacturing since it is a proxy for the space occupied by the equipment; factory space is very expensive ($3,500/ft^2 Source: SEMATECH). It is easy to measure and the objective is to minimize it.

Impact of manufacturing operations on natural environment:

- Number of hazardous materials: Semiconductor processing involves the application of chemicals and gases and this item will represent the number of such materials. The SEMATECH COO model partially captures this item as a raw material cost, but disposal cost which varies widely for different materials is not captured. It is moderately difficult to measure and the objective is to minimize it.
- Toxicity of materials involved: Related to the gases and chemicals used in manufacturing and is easily measured by well-defined and government-documented indices. The objective is to minimize it.
- Conversion efficiency: Refers to the percentage of material used that remains in the final product as opposed to being emitted as hazardous effluent; 100% conversion efficiency means there is zero emissions. It is also possible to conceptualize this item as a natural resource conservation item since minimizing emission reduces both economic and material waste. It is moderately difficult to measure due to the approximations involved in its calculation, and the objective is to maximize it.
- Recycled content: How much of the equipment is constructed from post-use material. It is easy to measure via supplier reporting and the objective is to maximize it.

- Recyclability: The ability to reuse the entire product in a different factory, industry, or reuse of its components. Profits are improved by revenue generation from its sale and cost savings by avoiding its disposal costs. It is difficult to measure because of large uncertainty in used equipment markets and the continuous evolution of recycling technologies. The objective is to maximize it.
- Greenhouse gas emissions (i.e. CO_2): The amount of effluent released into the atmosphere from use of such gases. CO_2 is gaining importance due to European Union regulations that require its reduction as a condition of selling in member countries. Other such gases in semiconductor production are Perfluorocompounds (PFCs). It is easy to measure and the objective is to minimize it.
- Demanufacturability: Related to time and effort needed for disassembly or dismantling which is indicative of design simplicity. The item implies that a simpler design is related to highly effective product development process that can encompass ecological constraints. It is moderately difficult to measure, has an indirect relation to ecological efficiency, and the objective is to minimize it.
- Remanufacturability: The ability to remake the equipment into another product that can extend its lifetime and is analogous to recyclability. Along with demanufacturability above, this attribute has gained increased relevance due to recent European Union regulations dictating that suppliers are responsible for the final

disposal of their products, hence extending a product's life or making it easy to disassemble are beneficial attributes. It is moderately difficult to measure and the objective is to maximize it.

- Upgradeability (Panel addition): The ability to extend the lifetime of a product by upgrading it for use in next generation technology processes. It is easy to measure and the objective is to maximize it.
- Product Packaging (Panel addition): Refers to recyclability, reusability, reduced energy, and reduced number of materials. It is easy to measure and the objective is to minimize it.
- Product Take-back (Panel addition): Analogous to recyclability, however it makes it explicitly the supplier responsibility. It is easy to measure and the objective is to maximize it.
- Full Disclosure (Panel addition): Related to customer concern about all materials used in operating the equipment. This maximizes the sharing of expertise and the objective is to maximize it.

Cost associated with regulations and end-of-life:

- Regulatory compliance cost: The cost associated with compliance with the relevant regulations. Perceptions of extent or scope of such regulations is also included as a separate possible economic importance determinant variable. It is moderately difficult to measure due to the inherent uncertainty of changing political environments that legislate such regulations. The objective is to minimize it.

- Disposal cost: Equipment disposal cost at the end of its useful life. Cost associated with final equipment disposal as well as the proper disposal of chemicals and gases used in its application. It is moderately difficult to measure and the objective is to minimize it.
- Waste Generation (Panel addition): Related to minimizing waste that would need to be disposed.
- Waste Segregation (Panel addition): Related to unavoidable wastes and the objective it to maximize it. The more segregated wastes are, the more efficiently they can be treated and/or dispose.

ECOLOGICAL CONCERN

This section includes a review of the academic and professional literature pertaining to measures related to the natural environment that have been published over the past few decades. The review encompasses marketing, psychology, business management, industry, and practitioner technical publications.

The earliest marketing attempt to examine ecological concern (discovered in this research) was presented it in the context of socially responsible consumption (Anderson and Cunningham 1972; Fisk 1973), and introduced the notion that consumers societal orientation, or sociopsychological variables, can be used to segment markets in addition to demographic and behavioral variables. Subsequent marketing research, in the context of consumer brand perceptions, examined ecological implications of consumption behavior and presented the construct more specifically as one of two dimensions, attitude and purchasing behavior, and empirically demonstrated that customers with different levels of ecological concern have systematically different cognitive maps (Kinnear and Taylor 1973).

Further exploration of the emerging construct was motivated by a realization that the ecology will likely play an increasing role in how marketers position their products, and investigated how personality and socioeconomic characteristics of consumers related to their ecological concern are used to gain additional insight into their profiles (Kinnear, Taylor *et al.* 1974).

Attitude towards environmental quality was also investigated in psychology research, where concern about ecological degradation was presented as a predictor attitude, along with a behavioral action dimension, which is consistent with earlier marketing research (Lounsbury and Tornatzky 1977). The Lounsbury and Tornatzky (1977) study found that concern about overpopulation was not to be a good predictor of attitude towards ecological quality; hence in this research it will only be considered in the ecological knowledge variable that is hypothesized to influence attitude.

A recent study aimed at conceptualizing and measuring ecological concern proposed an ecological knowledge dimension to be considered along with attitude and behavioral dimensions presented in earlier studies (Bohlen, Schlegelmilch *et al.* 1993), hence it is considered as a possible determinant of ecological concern in this research (Belk 1975).

The Bohlen and colleagues (Bohlen, Schlegelmilch *et al.* 1993) research provides an extensive source of literature about the subject as well as a comprehensive list of validated perceived knowledge indicators, ecological attitude statements, and behavioral statements that will be partially utilized in this research as illustrated by the variable sources in the various tables. Tables 2 above and Table 3 below present the items in the perceived ecological knowledge measure and items the ecological concern measure and their literature sources respectively. Both measures are subjected to scale validation procedures in this study.

Ecological Concern Statement Items	Citation
Ecological problem is exaggerated	Bohlen 1993, Lounsbury 1977
Buy products geared towards eco enhancement	Anderson 1972, Kinnear 1973, Lounsbury 1977
Importance of pollution as a sociatal problem	Kinnear 1973, Lounsbury 1977, Bohlen 1993 Antil 1979
Urge colleagues to consider ecological consequences	Kinnear 1973, (Starik and Rands 1995)
Perceived effectiveness of pollution abatement	Bohlen 1993, Kinnear 1974
Perceived effectiveness of behavior in source reduction	Cordano 2000, Kinnear 1974
Importance of recycling	Lounsbury 1977, Antil 1979
Magnitude of resource allocation for environmental protection	Bohlen 1993, Kinnear 1973 (Starik and Rands 1995)
Resource conservation	Bohlen 1993, Henion 1981, Lounsbury 1977, SIA 2003, Antil 1979, Cordano 2000
Environmental benefits do not justify the expense	Bohlen 1993, Kinnear 1973
Concern over well being of future generations	Bohlen 1993, Lounsbury 1977
Consideration of supplier environmental policies	Bohlen 1993
Consideration of ecology in future decisions	Bohlen 1993, Antil 1979
Importance of environmental issues	Bohlen 1993
Full disclosure of entire ecological impact	Antil 1979
Firms should always put profitability before ecology	Bohlen 1993, Kinnear 1973

Table 3: Ecological Concern Items

Ecological concern studies are predominantly oriented towards consumer behavior research with the objective of finding and profiling the "socially responsible" consumer niche (Henion 1981), and lack a business behavior perspective. However, there is a significant body of research that asserts delivering ecological customer value is a potential source of gaining positive market outcomes for industrial organizations (Hart 1995; Lawrence and Morell 1995; Porter and Linde 1995; Porter and Linde 1995; Starik and Rands 1995; Banerjee, Iyer *et al.* 2003).

The derived competitive advantage is related to tacit market knowledge development that enables product differentiation, establishment of an early mover position that is hard to imitate, and opening the door to occupy the unclaimed "reputation" space with respect to ecological performance (Hart 1995; Zhao, Droge *et al.* 2001). In addition, other proposed sources of competitive advantage include the external opportunity afforded by changes in emerging ecological management challenges (Lawrence and Morell 1995), optimization opportunities in the company-ecology link illustrated in Figure 3 above (Starik and Rands 1995), and improved resource productivity where pollution is viewed as economic waste (Porter and Linde 1995; Cordano and Frieze 2000). Despite the potential for product differentiation, creating new markets, lower long-term costs, and increased market share within motivated segments there is little or no marketing research on the implications of this trend of rising corporate concern about the natural environment (Banerjee, Iyer *et al.* 2003).

To exploit opportunities related to the increasing ecological concern suggested in the cited research, marketing strategy is necessarily pursued in synchronicity with customers' value expectations and outward market orientation as opposed to defining such value solely based on internal firm perceptions (Slater 1997; Woodruff 1997).

This research aims to extract latent customer needs by examining their personal ecological concern and beliefs about the usefulness of specific ecological product attributes, therefore a firm can be proactively market oriented, as well as extracting expressed assumptions about the perception of economic importance of those attributes in current decision models, in order to also be responsively market oriented (Narver, Slater *et al.* 2004); all in the effort to design products that will win customer trial evaluations and establish cooperative relationships with product users.

Since there is no readily obvious consolidation of underlying dimensions of the ecological concern items in Table 3, exploratory and confirmatory factor analysis described in the methodology section are used to determine if such consolidation is empirically and logically feasible, reliable, and valid. The same procedures are also used to develop belief and knowledge measurement scales.

The items in all three scales were derived from various related consumer and business research; hence they are subsequently specifically assessed by a research panel (discussed in Chapters 3 and 4) for appropriateness for use in this business-to-business context. For ecological concern, the items in Table 3 are meant to gauge the respondent's attitude towards the environment by presenting them as statements and soliciting an indication of the respondent's level of agreement as shown in the third question in Appendix A.

The following sections will present specific research questions and hypotheses derived from the literature review, whereas data collected to explore whether hypotheses can be supported aids in addressing the three research questions.

RESEARCH QUESTIONS

To address the general research question about ecological customer value in the semiconductor manufacturing market, to link it to resulting behavioral implications, and to achieve the research objectives, the following specific research questions are addressed:

1. How are users beliefs, about the usefulness of individual ecological product attributes in attaining industry expansion with reduced impact on natural resources, related to their purchasing and cooperation intentions? And are those relationships the same across found segments?
2. How are users ecological concern attitudes towards the natural environment related to their purchasing and cooperation intentions?
3. To what extent are the users' beliefs about ecological usefulness of product attributes related to attitudes towards the natural environment?

In order to address the research questions, reliable and valid measures of belief and attitude were established and a determination of how customers differ in their perceptions of ecological product attribute importances was made; in other words, it was ascertained that users could be segmented on the basis of attribute cost importance perceptions.

HYPOTHESES

The dimensionalities of the two main measurement scales of belief and ecological concern are not known *a priori*, hence, before they are used in testing the hypotheses related to the research questions, their scale unidimensionality, reliability, validity of each scale were ascertained. As expected, this process reduced their number of items needed to produce useful research constructs. Also, the previously validated perceived ecological knowledge scale used in this research was further refined by subjecting it to the same validation and scale item reduction procedures; this is done because the validation of the knowledge construct was previously carried out in a consumer context and therefore it must be validated in the industrial environment context.

After reliable and valid scales were established, and prior to testing the hypotheses below, it was empirically determined that attribute economic importance scores can be used as a meaningful segmenting basis for the semiconductor market. Therefore ecological belief and intention relationships in hypotheses 1a and 1b below were tested separately for each segment.

The following hypotheses are designed to empirically assess the major research relationships between ecological belief, ecological concern, and behavior as depicted in Figure 1. Hypotheses designated with 1x are related to the 1st research question, 2x are related to the 2nd research question, and 3 is related to the 3rd research question.

Hypothesis 1a:

Belief about the usefulness of ecological product attributes in each segment is positively related to the segment's intentions to include the ecological impact of products in their new product adoption decision process.

Hypothesis 1b:

Belief about the usefulness of ecological product attributes in each segment is positively related to the segment's intentions to form cooperative relationships with suppliers that focus on reducing ecological impact.

Hypothesis 2a:

Ecological concern attitude towards the environment is positively related to user intentions to include the ecological impact of products in their new product adoption decision process.

Hypothesis 2b:

Ecological concern attitude towards the environment is positively related to user intentions to form cooperative relationships with suppliers that focus on reducing ecological impact.

Hypothesis 3:

Ecological belief about the utility of ecological product attributes is positively related to ecological concern.

A secondary hypothesis is tested for a better understanding of ecological concern. Attitude is presented in the literature as a "learned" predisposition; hence there is a benefit to assessing the relationship between perceived ecological knowledge of various environmental issues and ecological concern.

Hypothesis 4:

Perceived ecological knowledge of users is positively related to their ecological concern attitude towards the environment.

CHAPTER 3

STUDY DESIGN AND METHODOLOGY

OVERVIEW

This research investigates the predictive relationships between ecological belief, attitude, and behavior intentions in the largely unexplored context of industrial marketing (Banerjee, Iyer *et al.* 2003); behavioral intentions are defined in terms of product adoption and long-term cooperation intentions. Product attribute importance forms the basis of customer segmentation (Scott and Bennett 1971), and associations between ecological knowledge and attitude (Bohlen, Schlegelmilch *et al.* 1993) as well as belief and attitude (Fishbein 1967) are examined.

A major objective is to determine if ecological product attributes are consequential in the industrial product adoption decision-making process. The evaluation stage of the adoption process depicted in Figure 2 involves the examination of beliefs about the usefulness of such attributes, and attitudes towards ecological impact of industrial activity, which in the conceptual model shown in Figure 1 are both hypothesized to predict customer trial testing and future joint technology development intentions.

To enable model generalization within the semiconductor industry, the research is performed at the industry level. The relevant class of products is front-end processing equipment, where hazardous materials are used, and which comprises the lion's share of and expenditure in semiconductor manufacturing; it is estimated that over 60% of the cost of a new factory, approximately \$2-\$3 billion, is spent on such equipment.

RESEARCH DESIGN

This research determines the extent to which beliefs about ecological product attributes predict users behavioral intentions, by applying a linear attitude model adapted for the context of the semiconductor capital equipment market, specifically quantifying predictive relationships in each of the found segments in the total sample population. This is accomplished by developing a scale for measuring customer beliefs about each attribute in terms of its ability to enable industry expansion with lower impact on the natural environment. The perceived economic importance of each attribute in the scale is used to segment the semiconductor manufacturing market.

The extent to which concern about the environment predicts the same users' intentions is also assessed. This necessitated development of a second scale for measuring customers' attitudes in terms of their response to particular statements related to ecological concern. Furthermore, since attitude along with belief are hypothesized to both be predictors of behavior, their relationship is also assessed. Finally, attitude is hypothesized to be learned, hence a perceived ecological knowledge scale is developed and its relationship with ecological concern is examined.

RESEARCH VARIABLES

Following is the reference ideal-state used to anchor beliefs about the usefulness of ecological product attributes: *Attainment of ecologically sustainable growth of the semiconductor manufacturing industry.*

INDEPENDENT VARIABLES

Belief and attitude are the two main independent variables, along with segmentation, determinant, and demographic variables.

- Belief: A measure of the degree to which increased R&D focus on each ecological product attribute (listed in the 1st question in Appendix A) enables or hinders attainment of semiconductor industry growth with reduced ecological impact. Measures the usefulness of each attribute in attaining the ideal-state.
- Attitude: Measures the degree of ecological concern regarding the natural environment. Measured via the level of agreement with statements presented in the 3rd question in Appendix A.

SEGMENTATION VARIABLE

- Economic importance perception: Measure of economic importance of each product attribute (listed in the 2nd question in Appendix A) in the company's current decision-making method; it improves the predictive ability of the independent belief variable.

DETERMINANT VARIABLES

- Knowledge: Measures knowledge about ecological issues listed in the 4th question in Appendix A. Hypothesized to be a determinant of the independent attitude of ecological concern.
- Regulation: This is an antecedent state distinguished by the fact a respondent brings it to the situation as opposed to being a result of it. Measures the extent to which local regulations are likely to have a systematic effect on ratings of economic importance (i.e. compliance costs and disposal costs). Measured as a continuous perception variable on a scale on 1 to 10 as stated in the 10th question in Appendix A.

DEPENDENT VARIABLES

Including a supplier in trial evaluations and forming long-term R&D relationships are the two main dependent variables, both of which are measured on a 7-point semantic differential scale as shown in questions 6 and 7 in Appendix A.

- Trial: A measure of the importance of the ecological impact of a product when deciding on which new products to include in trial evaluation, which precedes product purchasing or adoption.
- Cooperation: A measure of how actively users will seek out joint technology development partners on the basis of their attention to reducing ecological impact of their products.

DEMOGRAPHIC VARIABLES

- Sales: 2004 revenues estimated in US dollars.
- Size: In terms of the total number of employees.
- Integrated Device Manufacturer Status: Percentage of the production volume that is made for internal use (captive) as opposed to production volume dedicated to other companies (foundry).
- Executive Status: A binary measure of yes or no.
- Involvement: Level of involvement in product selection.
- Education level.
- Years of experience in semiconductor manufacturing.
- Leadership: Perception of the extent of a company's emphasis on adopting production practices that will minimize or forestall future regulations.
- Ecological know-how view: A perception of the whether ecological know-how is a critical function to be retained and controlled or a function to be outsourced.
- Ecological strategic importance: A perception of how reducing ecological impact is viewed, measured on a 7-point semantic differential scale.
- Ecological value: How environmental leadership is perceived.
- Ecological sustainability view: A binary measure of whether a respondent sees the trend as a cost or an opportunity

METHODOLOGY

SUBJECTS

Respondents were individuals involved in the manufacturing process engineering, planning, facilities, production, and procurement at semiconductor factories that utilize front-end capital equipment; designed for use to manufacture integrated circuit and telecommunication (ICT) devices. Due to the high complexity and costs associated with purchasing such equipment, procurement decision responsibility varies widely depending on the individual company procedures and centers of authority. Members of several functional groups are involved various ways in the decision process.

Recruitment of respondents was accomplished through cooperation and support from the Semiconductor Industry Association (SIA) and Semiconductor Equipment and Materials International (SEMI), the two largest global industry associations; the two associations work closely together. The objectives and methods of this research project were presented in person to both associations individually and collectively to solicit their support. Based on SIA's suggestion the English survey *and* cover letter were translated to Chinese, Japanese, and Korean to accommodate global members. They sent the response solicitation letter in 4 languages by e-mail shown in Appendix B to their membership; the e-mail text is shown in Appendix C. SIA and SEMI also agreed to allow the use of their names as supporters on the survey solicitation letter. It is estimated that the survey was sent to 1280 contacts.

MULTI-PERSPECTIVE RESEARCH PANEL

The initial version of the industry survey questionnaire was based on the outcome of an extensive literature review that resulted in the survey lists of 14 ecological product attribute items in Table 1, 13 ecological knowledge issues in Table 2, and 16 ecological concern statements in Table 3. Due to the lack of existing similar research, and to reflect the socioeconomic (multi-stakeholder) nature of this research, a multi-perspective 13-member panel was assembled to assess the comprehensiveness of the three survey lists, face validity of their concepts, their completeness, clarity, relative importance of each item, and to provide additional items they deemed important.

The panelists were high-level business executives in the semiconductor industry, a member of the board of directors of a semiconductor company, semiconductor-manufacturing engineers, environmental consultants with a semiconductor industry background, an ecologically sustainable development PhD academic, a waste elimination NGO's director who is an ex-CEO of a semiconductor company, and a government representative from the Oregon Department of Environmental Quality. Industry, community, and government were all represented in the panel composition.

Input from the panel was incorporated in the final questionnaire in Appendix A; which was used as the data collection instrument. The panel added 5 product attribute items, 3 ecological knowledge issues, and 4 ecological concern statements. In general, panelists' comments about the research study were encouraging.

DATA COLLECTION

After the research panel input was incorporated, the final survey was presented to the SIA and SEMI for distribution to their membership. Based on a suggestion from the SIA, the survey was translated to Japanese, Korean, and Chinese to simplify the task for global semiconductor professionals and to increase the likelihood of obtaining responses from outside the US. To minimize the loss of some meaning in the translations, each was done by a native speaker that lives and works (or has lived and worked) in the semiconductor industry in the US. The survey was officially launched at the International SEMATECH Manufacturing Initiative[6] (ISMI) conference in October 2005 and accepted responses for 11 weeks.

The survey instrument shown in Appendix A was posted on a survey website (http://survey.oit.pdx.edu/ss/wsb.dll/dawood/EcoSemi.htm) built using WebSurveyor software (which accommodated all 4 languages). Collected data resided on the Portland State University computer servers. The website was embedded in the survey letter shown in Appendix B and sent to SIA and SEMI member, and could be accessed by clicking on the embedded link.

As Shown in questions 1 thorough 4 in Appendix A, each respondent provided a rating of belief and importance for each ecological product attribute item, ecological concern statement, and ecological issue knowledge perception using a Likert-type semantic differential questions (Fishbein 1967).

[6] ISMI is a subsidiary of SEMATECH, and is the sole global organization focused exclusively on semiconductor manufacturing effectiveness. ISMI conducts programs in manufacturing infrastructure, methods, standards, and productivity, with the aim of reducing the cost of producing wafers and driving solutions to major productivity challenges (source: http://www.sematech.org/corporate/index.htm).

In the context of cognitive structures and attitude measurements, this is an acceptable method for obtaining valid and reliable measures; by having respondents judge the concept on the basis of bipolar evaluative scales (Osgood 1967). The two constructs of belief and ecological concern were subjected to exploratory factor analysis, followed by confirmatory factor analysis before their finalization for use in testing the hypothesized relationship. Importance perceptions of the same items used to measure belief were used to segment the semiconductor manufacturing market, and the presumably validated ecological knowledge scale was reevaluated for reliability and validity due to the fact it was not validated in an industrial context; rather in a consumer context.

PLANNED ANALYSES

The following material describes the plan for data analysis; hence the use of future tense. Chapter 4 describes the actual analyses.

In line with the exploratory nature of this research, belief and attitude response data will initially be characterized using descriptive statistics of means and ranges to get a sense of overall industry rating averages. These statistics will not be used for hypothesis testing or to address the research questions, but they may provide useful insights.

Reliabilities and validities of the ecological belief and ecological concern attitude constructs will be determined in order to generate scales that are adequate for use in subsequent analysis; since they will be used as unidimensional variables to test the research hypotheses. Assessment of measure validity for both constructs will be evaluated on conceptual and empirical criteria (Bohlen, Schlegelmilch *et al.* 1993; Parasuraman 2000).

Conceptual validity (i.e. content or face validity) will be achieved via the thoroughness with which the construct domain is established and the ability of the scale items to represent all relevant factors in that domain (Churchill 1979). This was accomplished via the extensive literature review, the face validity afforded by the multi-perspective research panel input, and the logical resulting factor structures. Empirical reliability and validity will be ascertained using exploratory and confirmatory factor analyses described in general in the next two paragraphs; a more detailed description is provided in Chapter 4.

An exploratory factor analysis will be performed on each scale items to assess their underlying factor structure (Bohlen, Schlegelmilch *et al.* 1993; Parasuraman 2000) using an orthogonal rotation routine to generate independent factors with zero correlation (Hair, Babin *et al.* 2003). Factor solutions that explain over 60% of total variance and have eigenvalues greater than 1 will be used as the starting point of the confirmatory factor analysis. Significance of factor loadings will be determined based on the actual sample size.

After the initial belief and attitude factor structures have been established, and the appropriate number of items retained, each construct's reliability will be determined using commonly applied Cronbach's alpha internal construct consistency measure (r), a value greater than 0.7 is commonly regarded as a strong reliability measure.

To assess each scale's empirical validity a confirmatory factor analysis will be conducted to determine if the resulting structure fits the data sufficiently by examining chi-square values and a multitude of goodness-of-fit measures explained in the next chapter (Parasuraman 2000; Narver, Slater *et al.* 2004).

The next phase of the analysis will determine if attribute importance perceptions, associated with the same items that make up the belief scale, form a sound basis for segmenting the semiconductor manufacturing market. Cluster analysis, that uses attribute items as axes, is used to determine if homogenous segments exist based on attribute importance (Scott and Bennett 1971). Euclidian distances and a hierarchical clustering routine will be used.

After logical and meaningful segments are found (although this turned out to be the case, it was not known *a priori*), discriminant analysis and an examination of Wilks' Lambda will be used to determine the utility of the segmentation in terms of correctly classifying members of each segment. To further ascertain segment validity the segment results will be compared based on the theoretically related variable of expressed ecological leadership strategy. The segmentation will also be assessed on univariate basis in a test of equality of group means and a multivariate basis by examining the Structure Matrix; these last two analyses will shed light on which attributes have the most predictive power; also know as determinant attributes (Engel, Blackwell *et al.* 1986).

After the data reduction has been completed, reliable and valid scales of belief and attitude have been found, and the market has been segmented, the following analyses will be used to test the hypotheses and address the research questions. For the proposed multiple regression and correlation analyses, it is assumed that the relationships between all variables being examined are linear, the sample data comes from normally distributed populations, and error terms are independent and distributed normally. The least squares method will be used to fit the data, and independent variables are measured using the same metric scales.

The primary goal of this research project, as presented in the first and second research questions, is to gauge whether beliefs about ecological product attribute usefulness and ecological concern attitudes can predict user behavioral intention. Multiple regression analysis will be used to assess the hypothesized predictive association between a validated belief scale and purchasing and cooperation intentions for each segment, and similar analysis will be performed between a validated attitude scale and intentions.

In the above regression analyses, the multiple coefficient of determination (R^2) will be examined to evaluate the strength of the linear association between each dependent variable and the independent variables representing each construct; R^2 is the proportion of the variability in the user intention variables that can be explained by the factors in each construct and it is expected to be small since a multitude of other issues not considered in this research influence such intentions. To determined if the overall regression model is statistically significant, the model F statistic will be examined at the 0.05 significance level. The strength of relationship between each factor in each construct will be assessed using coefficient betas to determine which ones make better predictors of behavioral intentions; significance will also be considered at 0.05 level.

Correlation analysis, which uses the same assumptions as above, will be used to test the third hypothesis associated with the third research question. Pearson correlation coefficients between belief and attitude factors will be examined to assess the presence, strength, and direction of their association. Some correlation may exist since both constructs are hypothesized to predict behavior, but belief and attitude are two distinct constructs (Bohlen, Schlegelmilch *et al.* 1993; Hair, Babin *et al.* 2003).

RESEARCH CONTROLS

SIA and SEMI agreed to send the survey response solicitation e-mail to their memberships only once, and no follow-up e-mails were possible due to spam policy. To determine if there is a non-response bias, mean ratings of early respondents and late respondents, for each item in the belief and attitude scales, were compared based on the assumption that subjects who respond less readily are more like non-respondents (Armstrong and Overton 1977). This was accomplished using a t-test to determine if there is a true difference in the means at 0.05 significance level. Early respondents were defined as the ones in the 1st quartile of responses and late respondents are the ones in the 4th quartile.

For further assessment of response time effects, a one-way analysis of variance was performed on the mean responses for each item in belief and attitude scales by way of splitting the total sample into 4 quartiles based on when the responses was received (i.e. 4 groups). The presence or lack of differences at the 0.05 significance level shed light on whether data in each quarter can reasonably belong to the same population (Hair, Babin *et al.* 2003).

Acquiescence bias was addressed by reverse coding approximately half of the attitude questions (Bohlen, Schlegelmilch *et al.* 1993). If an individual respondent did not respond to a particular item, all other responses from that individual will be dropped (i.e. listwise deletion). Respondents high education level lends further support to adequate data quality.

CHAPTER 4

ANALYSES AND RESULTS

OVERVIEW

This chapter provides details of all the analyses performed, each test's appropriateness for its particular purpose, the research related goal of each test, and a description of each test procedure. This chapter also presents the findings that are key to addressing the research questions, and discusses the meaning of the outcomes. An integrated discussion of all the findings will be presented in Chapter 5.

A survey questionnaire was developed and tested in order to establish product attribute ecological utility (belief) and ecological concern (attitude) measurement scales that will represent the two constructs. It was also used to collect data on user behavioral intentions, perceived economic importance of product attributes, level of ecological knowledge, perceptions of regulatory requirements, and several demographic variables listed in the Methodology chapter.

A description of the entire belief and attitude data is provided, along with a data reduction procedure that was followed to achieve reliable and valid attitude and belief measures. Customers are segmented based on economic importance to avoid making the wrong inferences about the belief and intentions relationships. Regression and correlation analyses are used to test the hypotheses and address the research questions.

A total of approximately 1280 semiconductor manufacturing professionals were surveyed and 131 responses were received representing an estimated 10 percent response rate, which is considered typical in such survey research where five to10 percent response rates are the norm (Alreck and Settle 1985; Zhao, Droge *et al.* 2001). In an analogous industrial survey, Daim (Daim 1998) cites numerous references indicating the acceptability of such response rate. Another survey study performed in an industrial context asserted a response rate just under seven percent may be deemed adequate (Tan, Lyman *et al.* 2002). The 10 percent response rate is likely due to the length, detail, and comprehensive nature of the survey, however its adequacy is strengthened by the degree the sample represents the entire industry as explained below.

Responses came from all relevant global semiconductor manufacturing hubs including the US, Japan, Europe, Korea, Taiwan, and Singapore. As indicated in Appendix B, subject confidentiality was assured and respondents were given the option of providing an anonymous e-mail address if they wished to receive a summary of the survey results; 17 respondents did not provide one, 47 respondents provided an internet based e-mail addresses, and 67 provided e-mail addresses that indicated company affiliations.

Responses came from companies that make up half of the production capacity of the $237 billion global semiconductor industry. Respondents came from every company in the 2005 top five worldwide market leaders representing over a third of the industry, seven of the top 10 companies and nine of the top 20 were also represented. This is in addition to SEMATECH assigned employees, four other companies not in the top 20, and the two largest global foundries based in Taiwan (TSMC and UMC) with combined revenues exceeding $11 billion; foundries do not design their own manufactured products and are not considered in the rankings. Figure 5 below shows the 2005 top 20 semiconductor companies; the ones that participated in the survey are highlighted.

Rank	Company	Revenue	% of Total	Headquarters
1	**Intel**	**$ 35,466**	**15.0%**	**US**
2	**Samsung**	**$ 17,210**	**7.3%**	**Korea**
3	**Texas Instrument**	**$ 10,745**	**4.5%**	**US**
4	**Toshiba**	**$ 9,077**	**3.8%**	**Japan**
5	**ST Microelectronics**	**$ 8,881**	**3.7%**	**Switzerland**
6	Infinion Technology	$ 8,297	3.5%	Germany
7	Renesas Technology	$ 8,266	3.5%	Japan
8	NEC Electronics	$ 5,710	2.4%	Japan
9	**Philips Semiconductor**	**$ 5,646**	**2.4%**	**Netherlands**
10	**Freescale Semiconductor**	**$ 5,598**	**2.4%**	**US**
11	Hynix	$ 5,560	2.3%	Korea
12	**Micron Technology**	**$ 4,775**	**2.0%**	**US**
13	Sony	$ 4,574	1.9%	Japan
14	Matsushita Electric	$ 4,131	1.7%	Japan
15	**Advanced Micro Devices**	**$ 3,917**	**1.7%**	**US**
16	Qualcomm	$ 3,457	1.5%	US
17	Sharp Electronics	$ 3,266	1.4%	Japan
18	Rohm	$ 2,909	1.2%	Japan
19	IBM Microelectronics	$ 2,792	1.2%	US
20	Broadcom	$ 2,671	1.1%	US
	Other Companies	$ 84,191		
	Total Revenue	**$237,139**		

Figure 5: 2005 Top 20 Semiconductor Companies.

Source: iSupply Corporation, El Segundo, CA March 2006

DATA QUALITY

The multi-perspective research panel input was an important fine-tuning mechanism for the survey instrument clarity and completeness, thus helping improve the quality of collected data. This section illustrates the reasons to conclude that the data is of sufficient quality by explaining how missing data was treated, comparing early and late respondents to assess non-response bias, and assessing response time effects to determine if there are differences in the mean levels of all belief and attitude items based on which time quartile the response was submitted; determine if the 4 subject quartiles based on response time can reasonably belong to the same population.

Fifteen subjects that were missing significant amounts of data were removed and the remaining 116 responses were used in data analysis. Since the remaining 116 subjects were missing some data in various sections of the survey, such data was deleted listwise (i.e. all the subject responses were removed for a particular test) due to the strong recommendation of such deletion when analyses involve correlation and covariance matrices (Zhao, Droge *et al.* 2001; Joreskog 2005).

Responses to reverse coded questions designed to minimize acquiescence bias (Bohlen, Schlegelmilch *et al.* 1993) were manually recoded, and reviewed twice, so that there is a consistent numbering scheme of the lowest number response selection indicating a worst-state and the highest number response selection indicating a best-state response.

This consistent response-numbering scheme along with the large number of categories (i.e. 7), and equal spacing of categories in the Likert-type scales enables the assumption that variables can be considered to have scale versus ordinal levels of measurement (Sproull 1995; Hair, Babin *et al.* 2003). Benefits of this scale measurement level assumption include meaningful means and standard deviations of responses as well as the ability to perform subsequent regression analyses and calculate Pearson correlation measures.

NON-RESPONSE BIAS

To determine if there is a non-response bias in the data, means of the 1st 25% of responses were compared with the last 25% for all 19 product attribute items that make up the belief measurement scale and the 20 statements that make up the ecological concern attitude scale. This time trends extrapolation basis is a valid method to determine the extent of non-response and is based on the assumption that subjects who less readily respond are more like non-respondents, "less readily" has been defined as answering later. This approach has a unique advantage since it eliminates the possibility of bias introduced by the stimulus itself if multiple survey waves were sent (Armstrong and Overton 1977). Waves were not possible due to SIA and SEMI agreement to send out the survey only once, and the test described above is able to demonstrate the lack of non-response in the data (Zhao, Droge *et al.* 2001).

The t-test parametric procedure to compare the 2 groups means is appropriate for variables measured on an interval scale, sample size is small ($n<30$), which is the case in this test where each quarter's sample size is 29, and although normal distribution is assumed this test is quite robust to departures from normality (Hair, Babin *et al.* 2003). Early respondents are defined as those in the 1st quartile of responses and late respondents are those in the 4th quartile.

The t-test determines if the observed differences, for each scale item mean, occurred by chance or if there is a true difference at the 0.05

significance level. This test also helps determine if there is a non-response problem in the data (Hair, Babin *et al.* 2003).

The null hypothesis is that there is no difference in the means; in other words the means are equal. The dependent variables are the individual scale items and the independent (grouping) variable is the quarter number. Table 4 below shows the results. Scale item descriptions were abbreviated slightly from the full description provided in Appendix A to be able to fit them on the page.

Results demonstrate that it is reasonable to assume there is no meaningful difference between rating levels of early and late responders. Only one of the 39 items showed a significant difference. It can be reasonably concluded that statistical difference is not present between the two mean responses of early and late respondents, and therefore non-response bias does not present a significant problem for subsequent analyses.

BELIEF	t	df	Sig.
Energy requirements	1.75	45	0.087
Water usage	0.77	45	0.447
Overall mass of product	0.73	45	0.470
Number of hazardous materials	0.54	45	0.593
Toxicity of materials needed	0.26	45	0.798
Conversion efficiency (i.e. low emissions)	-0.60	45	0.554
Recycled content in the physical product	0.57	45	0.575
Recyclability of product components	0.23	45	0.818
Green house gas emissions (i.e. CO_2)	0.30	45	0.762
Demanufacturability	0.05	45	0.957
Remanufacturability	-0.27	45	0.785
Regulatory compliance cost	0.67	45	0.505
Tool disposal cost at end of useful life	0.28	45	0.779
Generation of wastes during use	-0.10	45	0.919
Segregation of waste streams	1.47	45	0.149
Product packaging	0.13	45	0.898
Upgrade-ability (lifecycle extension)	0.58	45	0.567
Full disclosure for materials of concern to customers	-0.55	45	0.582
Product take-back for free or at minimal charge	0.85	45	0.401
ECO-CONCERN	t	df	Sig.
Our industry's ecological problems are exaggerated	-0.50	51	0.622
I seek products that have minimal ecological impact	-0.29	51	0.772
Pollution by our industry does not create a societal problem	-0.17	51	0.865
I urge colleagues to consider ecological consequences of products	-0.58	51	0.567
Pollution abatement is an effective ecological management tool	-0.01	51	0.990
Pollution prevention is an effective ecological management tool	-1.10	51	0.275
My individual behavior will not make a difference in preservation	-0.27	51	0.786
Recycling is not an important concept and behavior	-1.20	51	0.236
Not enough resources are allocated for environmental protection	0.63	51	0.534
Resource preservation should be a societal goal	-1.37	51	0.178
Ecological benefits do not justify the expense of R&D	-0.83	51	0.410
I am concerned over the well being of future generations	-0.35	51	0.725
Environmental policies should be considered in purchasing	2.60	51	0.012
Suppliers should not have to disclose ecological impact of products	0.52	51	0.603
It is possible to develop ecologically sound technology economically	1.29	51	0.202
Firms should always put profitability before ecological considerations	0.18	51	0.861
Environmental protection should be key element of corporate culture	0.29	51	0.771
Ecologically superior products should not cost more	0.79	51	0.435
Ecological issues should not be a factor in decision making	0.06	51	0.948
Manufacturers have a societal obligation for final disposal	-0.23	51	0.815

Table 4: Equality of Means Between Early and Late Respondents

COMPARING ALL RESPONDENTS

To further examine the response time effects, a One-Way Analysis of Variance (ANOVA) was used to assess the differences between the mean responses for each item in the belief and attitude scales for all 4 groups of respondents. Respondents were grouped based on the time-based quarter their input was received; the 116 data points were grouped in 4 quartiles of 29 responses each; group size supports normal distribution assumptions.

The purpose was to determine if there are differences in the mean levels of rating based on which quarter the response was submitted, this would shed light on whether data in each quarter can reasonably belong to the same population. The dependent variables are all 39 belief and attitude scale items and the independent non-metric variable is the 4-level quartile number.

Tables 5 and 6 below show the results of this analysis (the 8-character abbreviations shown in Appendix A were used for ease of display). Only 2 of 39 items exhibited group means that are not equal at the 0.05 significance level. Hence, it is reasonable to assume response means are not significantly different based on response time. This provides further confirmation of the results from the preceding t-test above in terms of the lack of a meaningful influence of when responses were received on the distribution of the data.

The t-test and ANOVA results demonstrate sufficient data set adequacy to proceed with subsequent analyses. Note that the observed effect size of >0.4 and the chosen alpha of 0.05 provide for an adequate statistical power >80% (Hair, Anderson *et al.* 1995).

		Sum of Squares	df	Mean Square	F	Sig.
B_ENERGY	Between Groups	13.448	3	4.4827	1.8210	0.1494
	Within Groups	211.708	86	2.4617		
B_WATER	Between Groups	22.027	3	7.3423	2.4962	0.0652
	Within Groups	252.962	86	2.9414		
B_MASS	Between Groups	3.228	3	1.0759	0.7633	0.5177
	Within Groups	121.228	86	1.4096		
B_HAZMAT	Between Groups	10.462	3	3.4874	1.2891	0.2833
	Within Groups	232.660	86	2.7053		
B_TOXCTY	Between Groups	10.152	3	3.3839	1.2009	0.3144
	Within Groups	242.337	86	2.8179		
B_CONVRT	Between Groups	4.588	3	1.5292	0.8247	0.4838
	Within Groups	159.468	86	1.8543		
B_RCYCLD	Between Groups	2.079	3	0.6930	0.3421	0.7950
	Within Groups	174.243	86	2.0261		
B_RCYCLB	Between Groups	0.342	3	0.1141	0.0539	0.9834
	Within Groups	182.158	86	2.1181		
B_GRNHGS	Between Groups	2.160	3	0.7201	0.3221	0.8094
	Within Groups	192.295	86	2.2360		
B_DMNFCT	Between Groups	0.332	3	0.1106	0.0566	0.9822
	Within Groups	168.068	86	1.9543		
B_RMNFCT	Between Groups	4.345	3	1.4482	0.7801	0.5082
	Within Groups	159.655	86	1.8565		
B_REGULT	Between Groups	5.333	3	1.7778	0.7792	0.5088
	Within Groups	196.222	86	2.2817		
B_DSPCST	Between Groups	2.577	3	0.8590	0.3866	0.7629
	Within Groups	191.079	86	2.2218		
B_WSTGEN	Between Groups	2.015	3	0.6718	0.2423	0.8666
	Within Groups	238.440	86	2.7726		
B_WSTSEG	Between Groups	5.942	3	1.9808	1.1916	0.3178
	Within Groups	142.958	86	1.6623		
B_PACKAG	Between Groups	1.886	3	0.6286	0.4093	0.7467
	Within Groups	132.070	86	1.5357		
B_UBGRAD	Between Groups	2.183	3	0.7277	0.4615	0.7099
	Within Groups	135.606	86	1.5768		
B_DSCLOS	Between Groups	6.943	3	2.3143	1.1524	0.3328
	Within Groups	172.713	86	2.0083		
B_TAKBAK	Between Groups	7.955	3	2.6518	1.1071	0.3508
	Within Groups	206.000	86	2.3954		

Table 5: Equality of Belief Item Means for All Respondents

		Sum of Squares	df	Mean Square	F	Sig.
C_EXGGRT	Between Groups	13.615	3	4.5382	1.7734	0.1575
	Within Groups	243.113	95	2.5591		
C_LOIMPC	Between Groups	6.642	3	2.2141	1.3460	0.2641
	Within Groups	156.267	95	1.6449		
C_SOCIET	Between Groups	14.988	3	4.9961	1.9106	0.1331
	Within Groups	248.426	95	2.6150		
C_CNSQNC	Between Groups	1.008	3	0.3358	0.1544	0.9266
	Within Groups	206.629	95	2.1750		
C_ABATE	Between Groups	0.630	3	0.2101	0.1231	0.9463
	Within Groups	162.097	95	1.7063		
C_PREVNT	Between Groups	2.419	3	0.8062	0.7556	0.5218
	Within Groups	101.359	95	1.0669		
C_MYBEHV	Between Groups	7.422	3	2.4740	1.2809	0.2854
	Within Groups	183.487	95	1.9314		
C_RECYLN	Between Groups	2.392	3	0.7973	0.7082	0.5495
	Within Groups	106.962	95	1.1259		
C_PROTCT	Between Groups	22.390	3	7.4632	3.1525	0.0285
	Within Groups	224.903	95	2.3674		
C_PRESRV	Between Groups	2.522	3	0.8408	0.6820	0.5652
	Within Groups	117.114	95	1.2328		
C_EXPENS	Between Groups	10.404	3	3.4679	1.5436	0.2083
	Within Groups	213.435	95	2.2467		
C_FUTGEN	Between Groups	0.325	3	0.1084	0.0672	0.9772
	Within Groups	153.331	95	1.6140		
C_POLCIS	Between Groups	11.429	3	3.8098	3.6463	0.0154
	Within Groups	99.258	95	1.0448		
C_DISCLS	Between Groups	5.470	3	1.8233	0.8988	0.4449
	Within Groups	192.712	95	2.0285		
C_ECNVLU	Between Groups	7.763	3	2.5875	1.2154	0.3085
	Within Groups	202.258	95	2.1290		
C_PROFIT	Between Groups	1.071	3	0.3571	0.1833	0.9075
	Within Groups	185.010	95	1.9475		
C_CULTUR	Between Groups	2.989	3	0.9962	0.8321	0.4795
	Within Groups	113.739	95	1.1972		
C_COSTSM	Between Groups	2.766	3	0.9219	0.3065	0.8207
	Within Groups	285.780	95	3.0082		
C_FACTOR	Between Groups	10.519	3	3.5062	2.6958	0.0503
	Within Groups	123.562	95	1.3007		
C_DISPOS	Between Groups	4.119	3	1.3729	0.5421	0.6547
	Within Groups	240.609	95	2.5327		

Table 6: Equality of Ecological Concern Item Means for All Respondents

DATA CHARACTERIZATION

This exploratory industrial marketing research project started out with only theoretical expectations and there were no analogous historical empirical studies that could have been used for insight. Hence, descriptive statistics for all responses are presented in this section to get a sense of overall industry rating averages. These analyses are not directly related to testing the research hypotheses, but are worthy of inspection nonetheless.

The means, ranges, standard deviations, and variances of all belief and ecological concern items are illustrated in Tables 7 and 8 below, and once again items were slightly reworded and shortened from the full descriptions in Appendix A for presentation purposes.

Table 7 shows how respondents rated their belief about each ecological product attribute in terms of its ecological usefulness. Focusing on reducing energy requirements is perceived to have the highest impact on enabling the attainment of ecological goals while focusing on reducing costs of regulatory compliance, though important, has have the lowest impact. All product attributes had a mean above the neutral point of 4. Toxicity of materials used exhibited the highest variance, and overall product mass had the lowest variance; likely due to its universal cost importance of minimizing the square footage any tool would occupy in the expensive factory space. Examining the ranges shows that energy and product packaging never rated at the minimum value of 1 implying a slight consensus of their relative usefulness.

Product Attribute Items	N	Min	Max	Mean	Std. Dev.	Variance
Energy requirements	116	2	7	5.41	1.57	2.45
Water usage	112	1	7	5.28	1.71	2.94
Conversion efficiency (i.e. low emissions)	109	1	7	5.23	1.36	1.85
Upgrade-ability (lifecycle extension)	116	1	7	5.10	1.27	1.62
Generation of wastes during use	115	1	7	5.00	1.70	2.89
Green house gas emissions (i.e. CO_2)	115	1	7	4.99	1.54	2.36
Segregation of waste streams	115	1	7	4.96	1.36	1.85
Product packaging	116	2	7	4.90	1.23	1.52
Toxicity of materials needed	113	1	7	4.82	1.73	2.99
Recyclability of product components	114	1	7	4.81	1.40	1.96
Number of hazardous materials	113	1	7	4.78	1.69	2.85
Full disclosure for materials of concern to customers	115	1	7	4.77	1.45	2.11
Recycled content in the physical product	116	1	7	4.63	1.41	1.97
Remanufacturability	116	1	7	4.61	1.43	2.05
Demanufacturability	115	1	7	4.56	1.40	1.95
Overall mass of product	114	1	7	4.54	1.14	1.29
Product take-back for free or at minimal charge	115	1	7	4.47	1.54	2.37
Tool disposal cost at end of useful life	114	1	7	4.25	1.49	2.22
Regulatory compliance cost	114	1	7	4.19	1.54	2.37

Table 7: Descriptive Statistics of Belief About Attribute Ecological Usefulness

Ecological Concern Attitude Statement	N	Min	Max	Mean	Std Dev	Variance
Recycling is an important concept and behavior	112	2	7	5.91	1.09	1.18
Pollution prevention is an effective management tool	112	3	7	5.90	0.99	0.97
Environmental protection is key in corporate culture	111	2	7	5.84	1.10	1.21
Resource preservation should be a societal goal	112	2	7	5.73	1.11	1.22
Ecological issues should be a factor in decisions	112	2	7	5.69	1.20	1.44
I am concerned over well being of future generations	111	1	7	5.64	1.26	1.60
Environmental policies to be considered in purchasing	113	2	7	5.50	1.07	1.15
Ecologically sound technology can be economical	113	1	7	5.40	1.43	2.05
I seek products that have minimal ecological impact	113	1	7	5.29	1.43	2.05
Suppliers disclose entire ecological impact of products	112	1	7	5.25	1.39	1.92
Pollution abatement is an effective management tool	114	1	7	5.14	1.23	1.52
Firms should always put ecology before profitability	112	2	7	5.12	1.37	1.87
Ecological benefits justify the expense of R&D	113	1	7	5.04	1.48	2.20
My individual behavior will make a difference	112	2	7	4.98	1.29	1.66
Manufacturers have an obligation for final disposal	111	1	7	4.87	1.53	2.35
Not enough resources allocated for environment	113	1	7	4.65	1.57	2.46
I urge colleagues to consider ecology consequences	114	1	7	4.61	1.42	2.03
Ecologically superior products should not cost more	108	1	7	4.52	1.69	2.85
Pollution by our industry creates a societal problem	112	1	7	4.42	1.60	2.55
Industry's ecological problems are not exaggerated	114	1	7	3.85	1.55	2.41

Table 8: Descriptive Statistics of Ratings of Ecological Concern Statements

Table 8 above illustrates how respondents rated each ecological concern statement designed to reflect their personal attitude towards the environment. The most positive attitude is associated with recycling, which is heavily emphasized in the industry's traditional "reduce-recycle-reuse" strategy (Helms 1997). The least positive attitude is related to the industry's ecological problems not being exaggerated; indicating an attitude the industry deserves credit for its recognition of the importance of ecological protection and its effort towards environmentally benign manufacturing. All other statements rated above the neutral level of agreement.

The highest attitude variance is in whether ecologically superior products should cost more, indicating a relatively widespread difference of opinions in terms of whether prices should be market driven versus the intangible worthiness of more ecologically benign products; in a sense this reflects the nature of the seemingly ubiquitous socioeconomic conflict. The lowest variance was in the effectiveness of pollution prevention, which was also a close second in mean ranking after the closely related concept of recycling. This indicates a relative consensus that avoiding pollution is the most favored approached to addressing the ecological impact of products and the industry. Pollution prevention also has the highest minimum value of 3, further supporting the above-mentioned consensus and possibly reflecting the industry's expanded new strategy/approach of "prevent-reduce-recycle-reuse".

CONSTRUCT UNIDIMENSIONALITY

Prior to examining the research relationships between ecological belief, attitude, and behavior, a unidimensional representation of the belief and attitude constructs must be established by verifying that indicators used to measure them have only their respective underlying concepts in common (Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995). The dimensionalities of the measurement scales used to represent the two constructs are not known *a priori*; hence before they are used in testing the proposed model relationships their reliabilities, and conceptual and empirical validities must be established.

A scale purification procedure, summarized in Table 9, using Exploratory Factors Analysis (EFA) followed by Confirmatory Factor Analysis (CFA) will be used to generate a reduced set of items, which will be empirically demonstrated as valid and reliable indicators of each construct (Fornell and Larcker 1981; Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995).

Unidimensionality was demonstrated by showing that indicators in each scale have an acceptable fit on a single-construct model (Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995). Unidimensionality is critical because it is an underlying assumption of scale reliability measures, such as the Cronbach alpha used in this research; which assume it exists (Fornell and Larcker 1981). Reliabilities are only meaningful if dimensionality can be established (Bohlen, Schlegelmilch *et al.* 1993; Hair, Anderson *et al.* 1995).

Conceptual validity is achieved via the extensive literature review that generated the initial list of each scale's items, input of the multi-perspective panel, and by generating meaningful factors or dimensions (factors analyses outcomes) that shed light on the underlying structure of each construct.

Exploratory Factor Analysis	**Criteria**
Principle Component Extraction	
Varimax Orthogonal Rotation - Independent Factors	
Eigenvalue	>1
Item's Factor Loading	>0.5
Item not loading on multiple factors	Yes
Total Variance explained	>60%
Reliability (Cronbach's Alpha)	>0.7
Confirmatory Factor Analysis	
Measures of Absolute Fit	
Significant Likelihood-Ratio Chi-Square (X^2)	<0.05
Root Mean Square Error of Approximation (RMSEA)	<0.08
Incremental Fit Measures	
Normed Fit Index (NFI)	>0.9
Tucker-Lewis Index (TLI or NNFI)	>0.9
Parsimonious Fit Measures	
Normed Chi-squared (Chi-Square/Degrees of Freedom)	1 to 5
Comparative Fit Index (CFI)	>0.9
Conceptual Validity	
Extensive Literature Review	
Multi-Stakeholder Panel	
Logical Factors Generated	

Table 9: Criteria Used to Establish Construct Unidimensionality

The above criteria are subjective and somewhat conservative (Zhao, Droge *et al.* 2001). The next four sections provide a detailed explanation of the factor analyses procedures and actual results. Later sections contain details regarding has the scales' re-specification and purification.

EXPLORATORY FACTOR ANALYSIS PROCEDURES

An Exploratory Factor Analysis (EFA) was used to determine the initial number of factors needed to effectively describe each construct. The factor solution under went an orthogonal rotation to generate independent uncorrelated factors, which is necessary for subsequent regression analyses and it is the most commonly used method in business research (Hair, Babin *et al.* 2003). The Varimax method was used to generate the most stable solution that also maximizes simplification and interpretability of factors (Kaiser 1974).

The sample size is appropriate given that the recommended minimum of 5 times the number of items to be factor analyzed (Hair, Babin *et al.* 2003). In the worst-case scenario for the ecological concern scale a minimum of 100 responses are needed if all 20 items are kept in the attitude construct; similarly a minimum of 96 responses are required for the belief scale. Several items were dropped from all scales in the course of factor analyses; hence sample size is certainly adequate.

The Principle Component factor extraction procedure was chosen for the EFA to find the minimum number of factors needed to account for the maximum portion of variance represented in the original set of variables. It is also more stable than Common Component extraction, and it is the most commonly used method in business research (Hair, Babin *et al.* 2003).

Only EFA factors with latent roots, or eigenvalues, exceeding 1 were retained so a factor would represent more variance than a single indicator item. Based on the sample size, and the 0.05 significance level, only items with loadings >0.5 on less than 2 factors will be retained in each factor (Hair, Anderson *et al.* 1995), and the factor solution should account for 60% of the variance. These criteria are commonly used and referenced in numerous methodology literature listed throughout this paper.

Also construct reliability, as measured by commonly used Cronbach's alpha (r) should be >0.7 (Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995; Parasuraman 2000; Hair, Babin *et al.* 2003; Narver, Slater *et al.* 2004). In addition to the above numerical judgment criteria, each factor has to be conceptually meaningful and be named to represent an underlying dimension. A simple structure factor solution, where each item has a high loading on only one factor, is desirable (Hair, Babin *et al.* 2003). The actual results of this analysis are presented (two sections ahead) together with confirmatory factor analysis results for ease of reference.

CONFIRMATORY FACTOR ANALYSIS PROCEDURES

After the initial EFA factor solution was found, a CFA was performed to assess the validity of the initial factor solution. The EFA/CFA process of re-specifying the measurement scale and/or reducing the indicator items set was repeated until a valid and reliable model was achieved (Anderson and Gerbing 1988).

The sample size is also appropriate for CFA analysis, where in addition to the requirement of the number of responses be at least 5 times the number of items in a scale, a sample of 100-200 is recommended for a meaningful significance of the Chi-Square statistic. This recommendation stems from the fact that a sample at or below the absolute minimum of 50 will likely not show significance between relationships, and a sample of more than 200 will make all, even non-consequential, relationships seem significant (Hair, Anderson *et al.* 1995; Parasuraman 2000).

The CFA uses the correlation matrix since it is the preferred data type when the purpose of a study is to uncover underlying relationships (Hair, Anderson *et al.* 1995) and to refine the construct by re-specifying the measurement model to generate a valid scale to be used in subsequent analysis. CFA provides the basis for determining if scale items are reliable and valid measures of each specified construct.

The 7 Structural Equation Modeling (SEM) steps that were followed in the CFA analysis are listed below (Hair, Anderson *et al.* 1995):

a. Theoretically based model: From literature, and multi-stakeholder panel.
b. Path diagram: Generated using the EFA described above.
c. Structural Equation Model (SEM): In CFA, the measurement model represented by the path diagram constitutes the entire SEM.
d. Input matrix: The correlation input matrix is used since the research objective is to uncover underlying relationships, in which case it is the preferred data type.
e. Assess identification of structural model: Problems occur if multiple variables were hypothesized to be indicators of two or more dimensions, which was not the case in this research. Also, items that were lone loaders on a factor and items that loaded >0.5 on more than one factor were eliminated.
f. Evaluate the goodness-of-fit: Fitness refers to the ability of a model to reproduce the data. There is no one criteria that can be used to assess CFA generated model fit (Hair, Anderson *et al.* 1995), hence it will be assessed based on several criteria recommended in the literature that includes absolute fit, incremental fit, and parsimonious fit measures:
    i. *Significant Likelihood-Ratio Chi-square Statistic* (X^2) is achieved at <0.05 (Fornell and Larcker 1981; Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995). This is the necessary initial indication that a proper and convergent solution is achieved. The LISREL software

utilized does not generate a path diagram if this condition is not achieved. This is not, however, sufficient indication of a model fit and other criteria such as the ones listed below must be examined.

ii. *Root Mean Square Error of Approximation (RMSEA)*: Represents the goodness-of-fit if the model were estimated in the entire population as opposed to only the sample drawn for estimation (Stieger 1990). A value less than 0.08 is recommended (Hair, Anderson *et al.* 1995).

iii. *Bentler Bonett Index also knows as the Normed Fit Index (NFI)*: A measure that provides a relative comparison of the proposed model to the null model; defined as a model in which all correlations are zero with all indicators perfectly measuring the construct. A value greater than 0.9 is recommended (Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995).

iv. *Tucker-Lewis Index also known as the Nonnormed Fit Index (NNFI)*: A way of evaluating factor analysis that has been extended to SEM, it combines a measure of parsimony into a comparative index between the proposed and null model; it measures parsimony and fit (Bentler 1990). It is interpreted as the NFI above, however there is a penalty for adding parameters. A value of >0.9 is recommended (Hair, Anderson *et al.* 1995; Parasuraman 2000).

v. *Normed Chi-squared (X^2/df)*: The ratio between (X^2) and degrees of freedom. Provides two ways of assessing model appropriateness. A value less than 1 is a sign of over-fitting a model and capitalizing on chance, and a value over 5 shows the model is not truly representative. It would ideally be between 2 and 3 (Hair, Anderson *et al.* 1995).

vi. *Comparative Fit Index (CFI)*: Provides a good basis for judging relative model fit by complementing the NFI and NNFI; CFI eliminates the small sample bias of NFI and has a smaller sampling variance than NNFI (Bentler 1990; Bollen and Long 1993). A value >0.9 is recommended but a value as low as 0.88 was deemed acceptable (Parasuraman 2000).

g. Iterative interpretation: Modification or re-specification of the model to reach an adequate fit indicating a valid measurement scale.

In summary, a Principle Component factor solution subjected to a Varimax orthogonal rotation that explains >60% of total variance, with reliability r>0.7, was used to reduce the many items in each measurement scale down to a few dimensions of underlying structure. Empirical validity was established using Confirmatory Factor Analysis as described above (Anderson and Gerbing 1988; Hair, Anderson *et al.* 1995). This last step was used to refine the scales and re-specify them if necessary to achieve empirical validity by eliminating the item with the lowest pattern coefficient and repeating the entire process.

THE ECOLOGICAL PRODUCT ATTRIBUTES BELIEF CONSTRUCT

The measure purification procedures explained in the preceding two sections were applied to the belief scale using SPSS software for the exploratory factor analysis and LISREL software for the confirmatory factor analysis. Variables were coded in 8-character format to accommodate SPSS and LISREL statistical softwares; these codes are written next to corresponding variables in Appendix A for ease of reference.

The initial EFA attempt resulted in a 4-factor solution that accounted for >69% of the total variance. However six of the 19 items (B_GRNHSG, B_TOXCTY, B_HAZMAT, B_WSTGEN, B_DMNFCT, AND B_RCYCLD) loaded >0.5 on more than one factor and in accordance with the above criteria were removed and a second attempt was made. The subsequent factor solution explained 61.99% of the total variance and resulted in a 3-factor structure, but it showed that B_MASS did not load at >=0.5 on any factor and therefore it was removed and a third attempt was made.

The third factor solution, based on the remaining 12 items, resulted in a desirable simple 3-factor structure, it accounted for 65.17% of the total variance, all factors had eigenvalues greater than 2, all items loaded >0.5 and none of them loaded on more than 1 factor, and Cronbach's alpha was 0.8732. The 3 factors can logically be related to resource conservation, manufacturing operations, and the regulatory environment. At this point the resulting exploratory solution was tested to assess measurement scale validity using LISREL via a CFA.

A feature in LISREL that helps with pre-screening solutions is that if a proper and convergent solution is not achieved in terms of X^2 significance, a path diagram would not be generated, in other words if a path diagram is generated than the first model fit criteria specified in Table 9 is met.

The measurement model was specified based on the third EFA 3-factor solution and a significant solution was generated by LISREL. However assessment of the model fit (Normed X^2=3.31/df, RMSEA=0.106, NFI=0.91, NNFI=0.93, CFI=0.95) indicated a need for re-specifying the model to seek a better fit. Hence B_WSTSEG was eliminated due to having the weakest pattern coefficient in the path diagram. Although B_RMNFCT had an identical low loading it was kept in accordance with the protocol of eliminating one item at a time. The EFA solution for the remaining 11 items showed that B_RMNFCT loaded >0.5 on 2 factors. Also an attempt to remove it before B_WSTSEG did not improve the model, hence B_RMNFCT was removed and a new list of 10 attributes was tested.

Table 10 illustrates the simple structure 3-factor solution produced by the EFA for the remaining 10 items. It explained over 67% of total variance, had eigenvalues greater than 1.7, retained the same factors generated by the 12 item solution, and an internal reliability of r=0.8378. Also, CFA of the 10-item factor solution resulted in a very good model fit.

All EFA and CFA statistical results that demonstrate empirical validity and reliability are shown in Table 11, and conceptual validity is confirmed by the generation of logical and meaningful factors that form in a simple structure

(Hair, Babin *et al.* 2003). Individual factor contributions to explaining the total variance are shown in Table 12. The two factors related to resource efficiency and reducing the ecological impact of operations explain half of the variance.

The CFA path diagram of ecological belief's 3 underlying dimensions is shown in Figure 6, and the model was retained as the final solution representing the ecological belief construct's measurement scale.

While Table 10 illustrates the belief construct's factor structure, factor loadings of each attribute, and attribute items making up each factor, variables are presented in the 8-character format for space consideration. Table 13 provides a fuller description of the same factors and illustrates the three dimensions that represent belief about ecological usefulness of product attributes:

1. Reduced ecological impact of manufacturing *operations* (B_OPERAT).
2. Efficient use of natural *resources* – conservation (B_RSOURC).
3. Reduced *regulatory* compliance and disposal costs – end-of-life (B_LAW).

The factors are mostly similar to expectations, as described in the literature review where ecological footprint attribute items were discussed. Conversion efficiency was an exception since it ended up with resource conservation as opposed to reducing impact of operation; this remains a logical outcome since minimizing emissions is synonymous with maximizing efficiency of resource use.

Rotated Component Matrix		Component		
Product Attribute Indicator Item	Code	B_OPERAT	B_RSOURC	B_LAW
Product take-back free or at minimal charge	B_TAKBAK	0.766		
Upgrade-ability (lifecycle extension)	B_UBGRAD	0.700		
Full disclosure for materials of concern	B_DSCLOS	0.672		
Product packaging	B_PACKAG	0.669		
Recyclability of product components	B_RCYCLB	0.629		
Water usage	B_WATER		0.868	
Energy requirements	B_ENERGY		0.858	
Conversion efficiency (i.e. low emissions)	B_CONVRT		0.802	
Regulatory compliance cost	B_REGULT			0.855
Tool disposal cost at end of useful life	B_DSPCST			0.848
Extraction Method: Principal Component Analysis.				
Rotation Method: Varimax with Kaiser Normalization				

Table 10: Belief Construct's Factors Structure and Loadings

Exploratory Factor Analysis	Criteria	Result
Eigenvalue	>1	>1.7
Item's Factor Loading	>0.5	>0.629
Item not loading on multiple factors	Yes	Yes
Total Variance explained	>60%	67%
Reliability (Cronbach's Alpha)	>0.7	0.8378
Confirmatory Factor Analysis		
Measures of Absolute Fit		
Significant Likelihood-Ratio Chi-Square Statistic (X^2)	<0.05	0
Root Mean Square Error of Approximation (RMSEA)	<0.08	0.061
Incremental Fit Measures		
Normed Fit Index (NFI)	>0.9	0.94
Tucker-Lewis Index (TLI or NNFI)	>0.9	0.98
Parsimonious Fit Measures		
Normed Chi-squared (X^2/Degrees of Freedom)	1 to 5	2.25
Comparative Fit Index (CFI)	>0.9	0.98

Table 11: Belief Construct Validity and Reliability Results

Total Variance Explained - Rotation Sums of Squared Loadings			
Component	Total	% of Variance	Cumulative %
B_OPERAT	2.541	25.413	25.413
B_RSOURC	2.434	24.341	49.753
B_LAW	1.735	17.350	67.103

Table 12: Belief Factors Contribution to Variance Explanation

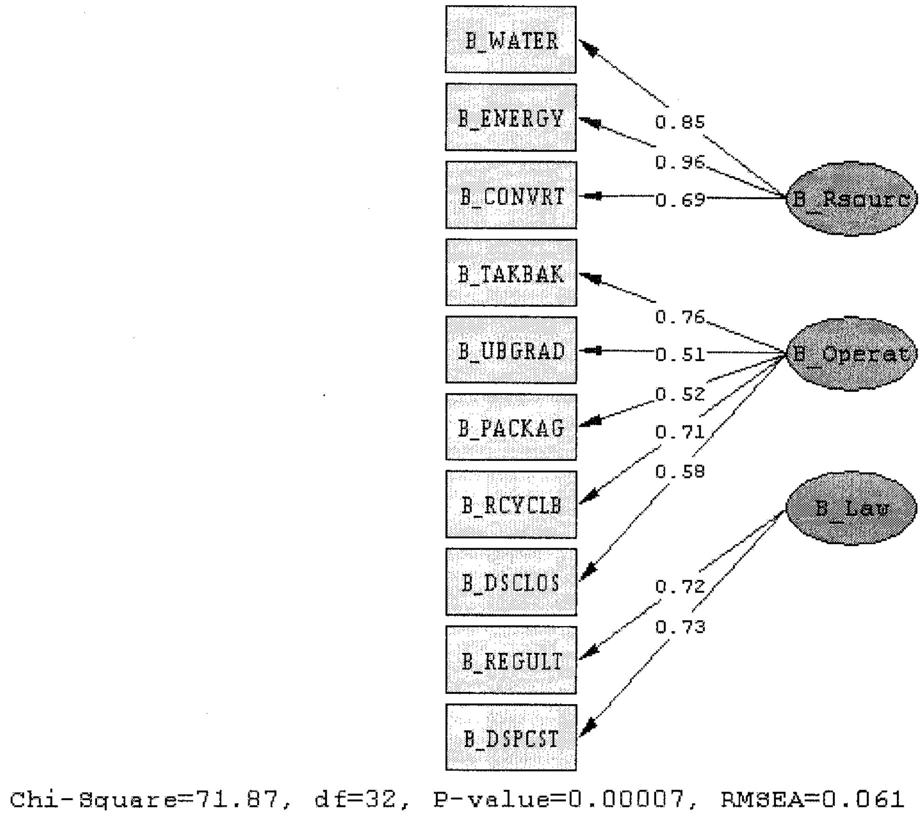


Figure 6: Belief Confirmatory Factor Analysis Path Diagram

B_OPERAT	**Reduced ecological impact of manufacturing *operations***
	Recyclability of product components
	Product packaging (reduced energy and materials, recyclability, and reuse)
	Upgrade-ability (lifecycle extension)
	Full disclosure for materials of concern to customers
	Product take-back for free or at minimal charge
B_RSOURC	**Efficient use of natural *resources* – conservation**
	Energy requirements
	Water usage
	Conversion efficiency (i.e. low emissions)
B_LAW	**Reduced *regulatory* compliance and disposal costs – end-of-life**
	Regulatory compliance cost
	Tool disposal cost at end of useful life

Table 13: Descriptions of Belief Factors Related to Ecological Usefulness

THE ECOLOGICAL CONCERN ATTITUDE CONSTRUCT

The same measure purification procedures were applied to the ecological concern attitude scale. The initial EFA 5-factor solution, which accounted for only 58% of total variance, showed that C_CULTUR and C_ECNVLU did not reach 0.5 loading on any factor and hence they were removed. The subsequent 5-factor solution accounted for 60% of the variance, however C_PRESRV never reached 0.5 and was removed. The following solution showed C_CNSQNC loaded higher than 0.5 on 2 factors and was also removed. Using similar criteria the following items were removed in subsequent analysis: C_DISCLS, C_FUTGEN, C_EXGGRT, C_LOIMPC. The item C_COSTSM was removed due to being the only item that loads on one factor.

The remaining 11 items generated an EFA solution of 4 factors with a simple structure accounting for over 65% of variance, had eigenvalues greater than 1.4, and a Cronbach's alpha r=0.707; hence the construct was ready for a CFA. The resulting CFA model was marginal with only two of the model fit criteria falling in an acceptable range (Normed X^2=3.81/df, RMSEA=0.129, NFI=0.8, NNFI=0.79, CFI=0.86); the measurement model items will now be investigated for re-specification.

Items with the lowest pattern coefficients were removed from the scale one at a time starting with C_MYBEHV, which resulted in a worst solution. The next lowest C_PREVNT was removed and the remaining 10 items reanalyzed. However LISREL would not allow 1 item to indicate 1 latent factor; which also goes against initial model determination criteria above, hence C_ABATE was also removed.

The remaining 9 Items generated a solution with a significant X^2, however the fit statistics were worst than the previous11-item solution. Examining the factor solution at a slightly lower loading level (0.4) showed C_SOCITY loaded on all factors, hence it was removed and the 8-item model tested, and once again generated an even worst fit. Finally C_FACTOR was removed for a similar reason and model fit did not improve.

At this point, since no obvious items were removal candidates, an iterative process of removing each of the 11 items, that generated the initial significant solution, one at a time and observing the effect was conducted. Removing C_PROTCT resulted in the best solution and was one of 4 indicators for one factor; the factor would remain in the resulting 10-item factor solution. All other factors also had 3 items or less, so the structure of the solution was not affected.

EFA of the remaining 10 items resulted in a simple 4-factor structure that explained 66.25% of total variance, had eigenvalues ranging from 1.36-2.07, and a Cronbach's alpha of r=0.69; a minor violation of the 0.7 criteria. Factors are logically related to personal attitude, attitude towards industry's responsibilities, attitude towards individual company practices, and a general attitude that avoiding pollution is a superior approach. Table 14 illustrates the ecological concern construct's factor structure, factor loadings of each ecological statement, and statement items making up each factor.

CFA generated an acceptable model fit and a summary of statistical results that demonstrate EFA and CFA empirical validity and reliability are shown in Table 15. Conceptual validity is confirmed by the generation of logical and meaningful factors that form a simple structure. Individual factor contributions to explaining the total variance are shown in Table 16. The relatively more subjective ecological concern scale did not exhibit as high of a robustness as the belief scale with lower pattern coefficients and 3 very minor violations of the pre-set criteria; however it is considered an acceptable scale due to the inherit difficulty in measuring subjective social constructs.

The CFA path diagram 4-factor solution of the 10-item factor solution is shown Figure 7, and will be retained as the final solution for the ecological concern attitude construct's measurement scale. Table 14 shows the factor loadings of its measurement scale indicator items, and Table 17 shows the factor descriptions.

Table 17 provides a fuller description of the same factors and illustrates the four dimensions that represent attitude about ecological concern:

1. Personal attitude and behavior (C_PERSNL).
2. Attitude towards industry's collective responsibility (C_INDUST).
3. Attitude towards individual company's business practices (C_BUSINS).
4. General Attitude that avoiding pollution is an optimal approach (C_AVOID).

Unlike the belief scale, there were no *a priori* expectations of the factor structure dimensions of ecological concern, however statement items in each factor have a strong logical relationship with the factor.

In summary, the Eco-Concern attitude construct is represented by the four dimensions of personal attitude and behavior (C_PERSNL), attitude towards industry's responsibilities (C_INDUST), attitude towards company-level business practices (C_BUSINS), and the attitude that avoiding pollution is an effective approach to addressing the issue of ecological degradation (C_AVOID).

Rotated Component Matrix		Component			
Ecological Concern Statement	Codes	C_PERSNL	C_INDUST	C_BUSINS	C_AVOID
Eco benefits justify R&D expense	C_EXPENS	0.75			
My behavior makes a difference	C_MYBEHV	0.74			
Recycling is an important behavior	C_RECYLN	0.73			
Manufacturers have to dispose	C_DISPOS		0.82		
Eco policies matter in purchasing	C_POLCIS		0.71		
Industry pollution is a problem	C_SOCIET		0.57		
Firm profitability before ecology	C_PROFIT			0.82	
Ecology is a factor in business	C_FACTOR			0.56	
Pollution abatement is effective	C_ABATE				0.92
Pollution prevention is effective	C_PREVNT				0.54
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					

Table 14: Ecological Concern Construct's Factor Structure and Loadings

Exploratory Factor Analysis	**Criteria**	**Result**
Eigenvalue	>1	>1.36
Item's Factor Loading	>0.5	>0.54
Item not loading on multiple factors	Yes	Yes
Total Variance explained	>60%	66.25%
Reliability (Cronbach's Alpha)	>0.7	0.69
Confirmatory Factor Analysis		
Measures of Absolute Fit		
Significant Likelihood-Ratio Chi-Square Statistic (X^2)	<0.05	0
Root Mean Square Error of Approximation (RMSEA)	<0.08	0.09
Incremental Fit Measures		
Normed Fit Index (NFI)	>0.9	0.88
Tucker-Lewis Index (TLI or NNFI)	>0.9	0.9
Parsimonious Fit Measures		
Normed Chi-squared (X^2/Degrees of Freedom)	1 to 5	2.73
Comparative Fit Index (CFI)	>0.9	0.93

Table 15: Ecological Concern Construct Validity and Reliability Results

Total Variance Explained - Rotation Sums of Squared Loadings			
Component	Total	% of Variance	Cumulative %
C_PERSNL	2.07	20.72	20.72
C_INDUST	1.69	16.88	37.60
C_BUSINS	1.50	15.00	52.60
C_AVOID	1.36	13.65	66.25

Table 16: Ecological Concern Factors Contribution to Variance Explanation

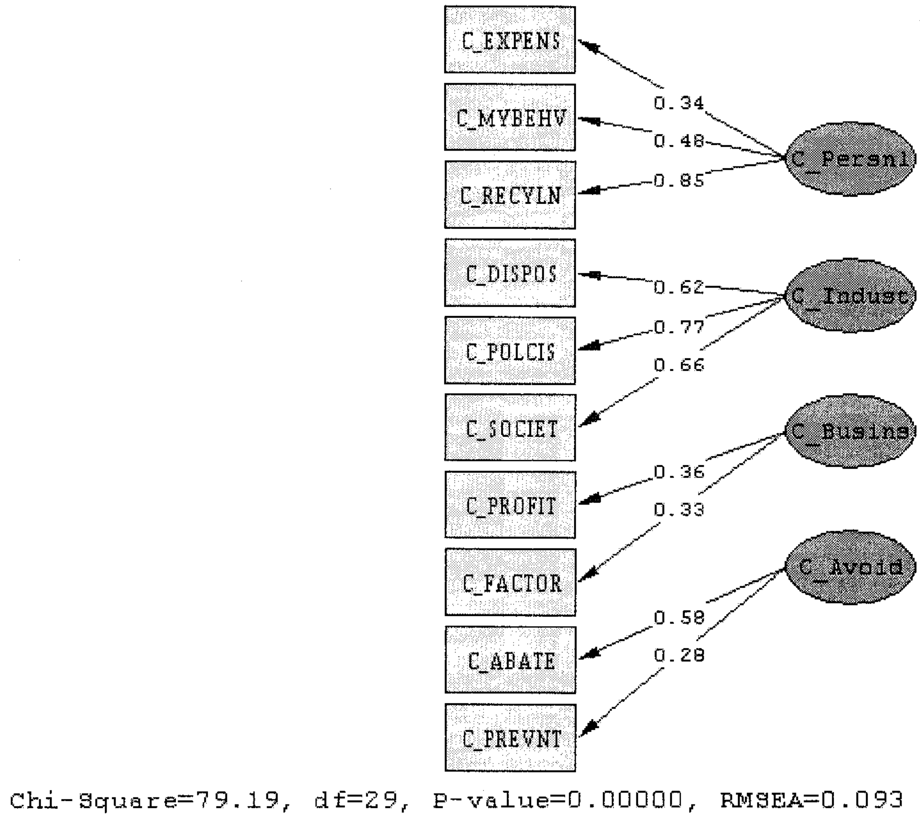


Figure 7: Ecological Construct Confirmatory Factor Analysis Path Diagram

	Description of Factors Related to Ecological Concern
C_PERSNL	**Personal Attitude and Behavior**
	Ecological benefits justify the expense of R&D
	My individual behavior will make a difference in natural resource preservation
	Recycling is an important concept and behavior
C_INDUST	**Attitude Towards Industry's Collective Responsibility**
	Manufacturers have a societal obligation for final disposal of their products
	Supplier environmental policies should be considered in purchasing decisions
	Pollution caused by our industry does not create a societal problem
C_BUSINS	**Attitude Towards Individual Company's Business Practices**
	Firms should always put profitability before ecological considerations
	Ecological issues should be a factor in business decision making
C_AVOID	**General Attitude That Avoiding Pollution is an Optimal Approach**
	Pollution abatement is an effective ecological management tool
	Pollution prevention is an effective ecological management tool

Table 17: Descriptions of Attitude Factors Related to Ecological Concern

As a final note before embarking on subsequent analyses, the process of refining the two belief and ecological concern demonstrated that even when a highly reliable EFA solution is reached, it does not necessarily mean that this solution is valid based on CFA model fit.

Next, the product attributes that were retained in the final scale representing the ecological usefulness belief construct were evaluated in terms of their ability to act as meaningful segmentation axes of the semiconductor manufacturing market.

MARKET SEGMENTATION BASED ON ATTRIBUTE IMPORTANCE

The ability of belief about ecological attributes to predict user intentions is improved by testing such relationship for each segment (as opposed to the entire population) based on how much economic importance the segment places on each ecological attribute. Attribute economic importance matters when differences between users' perceptions of it exist (Scott and Bennett 1971). Hence, prior to testing the belief and intention relationships, it must be ascertained if the industry can be meaningfully segmented on the basis of product ecological attributes economic importance perceptions, verify those segments are in fact different, and describe their profiles based on demographic characteristics.

Since belief and importance perceptions are both relative to specific ecological product attributes, the importance attribute items must be made to mirror the attribute items that make up the validated belief scale; this is possible because the survey in Appendix A collected responses of belief and importance on identical lists of product attributes.

In order to identify segments of respondents that have distinctively different perceptions of economic importances, cluster analysis will be used to assess if the presumably heterogeneous semiconductor manufacturing market contains homogenous subsets that can be identified; which are helpful in uncovering patterns that are otherwise difficult to identify (Scott and Bennett

1971; Hair, Babin *et al.* 2003). The independent variables are the 10 items making up the final belief construct scale.

Hierarchical clustering procedures were used since it is a well-accepted method to objectively identify initial cluster seeds. The squared Euclidean distance measure was used, because it has the fewest weaknesses compared with other options (Hair, Babin *et al.* 2003). A 2-cluster solution was sought due to the practical considerations of high costs and high risks associated with developing new products in the semiconductor industry. This dictates an individual company can only focus their marketing efforts on 1 or 2 segments; segmenting the market into smaller subsets is unreasonably costly and overly risky for the vast majority of semiconductor equipment companies.

The most commonly used agglomerative buildup approach was utilized to determine the appropriateness of a 2-cluster solution by examining the drop in agglomeration (i.e. error) coefficients. The Dendogram chart was used determine the size of each cluster and to spot outliers in the data, which are problematic in cluster analysis (Hair, Anderson *et al.* 1995).

The Ward clustering method option was used to calculate the clusters, since it is the most popular, tends to result in clusters with approximately the same number of objects, minimizes within-cluster differences, and avoids problems with "chaining" of the observations found in average linkage methods (Hair, Anderson *et al.* 1995; Hair, Babin *et al.* 2003).

To verify the 2-cluster solution is adequate, attribute item means in each cluster were tested for equality to assess if they are significantly different at 0.05, indicating the presence of homogenous subsets, or segments, in the market.

The two-cluster solution used 101 of the 116 respondents since subjects missing any rating on any item were deleted listwise. This resulted in grouping 44 respondents in the 1st segment and 57 in the 2nd segment. Segment sizes are similar enough and sufficiently large percentage-wise to justify possible variations in alternative marketing strategies or product development.

Table 18, showing an analysis of agglomeration coefficients, provides support that the number of clusters chosen (2) is empirically sound since the drop in the coefficient from 1 to 2 clusters is relatively much higher than the drops from 2 to 3 clusters and so on. An examination of the dendogram chart does not show any long branches that did not join until very late, indicating there are no problematic outliers in the data set (Hair, Anderson *et al.* 1995). The dendogram also shows that a 3 or a 4 cluster solution would result in segments that are very small and a large variation in cluster sizes; hence lending further support to the appropriateness of the 2-cluster solution chosen.

Agglomeration Schedule Ecological Attribute Importance			
No. of Clusters	Agglomeration Coefficient*	Change in Coefficient	% Change to Next Level
7	926.07	50.83	5.5%
6	976.90	65.59	6.7%
5	1042.48	95.80	9.2%
4	1138.28	135.18	11.9%
3	1273.47	140.17	11.0%
2	1413.64	438.88	31.0%
1	1852.52		
* Ward Method = Within-Cluster Sum of Squares			

Table 18: Analysis of Importance Agglomeration Coefficients (Hierarchical)

UTILITY OF MARKET SEGMENTATION

This section examines the segmentation results to determine if the identified groups are statistically different and if the segmentation scheme is theoretically meaningful. The results of the 2-cluster solution were compared to a theoretically related variable for validation. Discriminant analysis using Wilk's Lambda was used to determine the utility of the segmentation, and the segmentation was assessed on bivariate and multivariate basis to determine which attributes have the most predictive power.

Table 19 illustrates that the differences between the 2 group means are highly significant so the identified segments are in fact statistically different. Table 20 describes the 2 segments in terms of their mean ecological attribute importance ratings. Comparing their means provides a clear indication that group 1 has a low perception of ecological attributes economic importance and group 2 has a high perception of ecological attributes economic importance; the 2-cluster solution is theoretically meaningful.

Thus, there are two statistically different and meaningful segments of the semiconductor manufacturing and the remainder of this section will empirically evaluate the validity and practical utility of such segmentation.

Segment 1: Users who have *low perception of economic importance* of ecological product attributes. Segment is named *Cost-Centric*.

Segment 2: Users who have *high perception of economic importance* of ecological product attributes. Segment is named *Eco-Proactive*.

Ecological Product Attribute		Sum of Sq'rs	df	Mean Sq'r	F	Sig.
Energy Requirements	Between Groups	87.50	1	87.503	78.65	0.00
	Within Groups	110.14	99	1.113		
	Total	197.64	100			
Water Usage	Between Groups	66.59	1	66.589	44.32	0.00
	Within Groups	148.74	99	1.502		
	Total	215.33	100			
Conversion Efficiency	Between Groups	48.91	1	48.914	37.33	0.00
	Within Groups	129.72	99	1.310		
	Total	178.63	100			
Recyclability of components	Between Groups	32.81	1	32.813	23.63	0.00
	Within Groups	137.48	99	1.389		
	Total	170.30	100			
Regulatory compliance cost	Between Groups	9.76	1	9.756	6.14	0.01
	Within Groups	157.23	99	1.588		
	Total	166.99	100			
Disposal cost at end of useful life	Between Groups	39.60	1	39.596	25.55	0.00
	Within Groups	153.41	99	1.550		
	Total	193.01	100			
Product packaging	Between Groups	55.90	1	55.901	35.95	0.00
	Within Groups	153.94	99	1.555		
	Total	209.84	100			
Upgrade-ability (lifecycle extension)	Between Groups	25.47	1	25.469	16.25	0.00
	Within Groups	155.16	99	1.567		
	Total	180.63	100			
Disclosure for materials of concern	Between Groups	28.48	1	28.482	20.19	0.00
	Within Groups	139.66	99	1.411		
	Total	168.14	100			
Product take-back	Between Groups	43.86	1	43.855	33.88	0.00
	Within Groups	128.14	99	1.294		
	Total	172.00	100			

Table 19: ANOVA Results for the 2-Cluster Solution of Economic Importance

Ecological Product Attribute	Group	N	Mean
Energy Requirements	Cost-Centric	44	4.00
	Eco-Proactive	57	5.88
Water Usage	Cost-Centric	44	4.20
	Eco-Proactive	57	5.84
Conversion Efficiency	Cost-Centric	44	4.00
	Eco-Proactive	57	5.40
Recyclability of product components	Cost-Centric	44	3.11
	Eco-Proactive	57	4.26
Regulatory compliance cost	Cost-Centric	44	4.64
	Eco-Proactive	57	5.26
Tool disposal cost at end of useful life	Cost-Centric	44	3.39
	Eco-Proactive	57	4.65
Product packaging	Cost-Centric	44	3.11
	Eco-Proactive	57	4.61
Upgrade-ability (lifecycle extension)	Cost-Centric	44	4.64
	Eco-Proactive	57	5.65
Full disclosure for materials of concern	Cost-Centric	44	4.23
	Eco-Proactive	57	5.30
Product take-back free or at minimal charge	Cost-Centric	44	3.25
	Eco-Proactive	57	4.58

Table 20: Mean Economic Importances for Each Segment

To determined if the segments are valid, the 2 groups cluster results were compared with a theoretically related variable (Hair, Babin *et al.* 2003). The survey variable measuring the emphasis a company puts on adopting manufacturing practices that would render future regulations unnecessary (on a scale of 0 to 10) will be used. The variable is coded LEADSHIP in the software and Ecological Leadership in Table 21.

It is logical the Eco-Proactive segment with a “high” perception of economic importance of ecological product attributes would emphasize such leadership more than a Cost-Centric segment with a “low” economic perception. Table 21 shows the results of this test and it is verified that Eco-Proactive, with the higher perception, also has a higher emphasis on adopting practices that would minimize the need for regulations, and the two groups are significantly different, therefore establishing predictive validity for the 2-cluster solution.

	Group	N	Mean	Std. Deviation	Std. Error Mean
ECOLOGICAL LEADERSHIP	Cost-Centric	44	**5.95**	2.39	0.36
	Eco-Proactive	57	**6.96**	2.01	0.27
t-test for Equality of Means					
	t	df	Sig.	Mean Difference	Std. Error Difference
ECOLOGICAL LEADERSHIP	-2.306	99	**0.023**	-1.010	0.438

Table 21: T-Test Results For Two-Cluster Ecological Leadership Emphasis

To gauge the effectiveness of this segmentation scheme, discriminant analysis was used to determine if attribute importance items can be used to predict group membership in the 2 clusters and if their means are statistically different. Table 22 below shows Wilk's Lambda, which indicates the discriminant function has identified a statistical difference between the two segments, and that function accurately predicts Cost-Centric membership 95% of the time and Eco-Proactive membership 96% of the time, with an impressive overall predictive ability (hit ratio) of 96%.

Prior to profiling users in each segment, it is useful to uncover which attribute items have the most power in predicting the segments. This is done on a univariate and multivariate basis. Table 23 shows the univariate test of equality of group economic importance means, which indicates all attributes are significantly different and have the potential to be good predictors. To examine the attributes on multivariate basis the Structure Matrix in Table 24 is examined. The Structure Matrix correlations are used because they are considered more accurate, and the numbers represent the correlation between individual attributes importances and the linear combination of all attributes, where a correlation greater than 0.3 is considered a helpful predictor (Hair, Babin *et al.* 2003). The 3 most predictive attributes are energy, water and conversion efficiency, which are the same attributes that make up the natural resource conservation factor in the belief construct. Product packaging and take-back also have relatively high predictive power.

Wilks' Lambda					
Test of Function(s)	Wilks' Lambda	Sig.			
1	0.341	0.000			
Classification Results		Predicted Group Membership			Total
		Group	1	2	
Original	Count	1	42	2	44
		2	2	55	57
	%	1	95.45	4.55	100
		2	3.51	96.49	100
	96.0% of original grouped cases correctly classified.				

Table 22: Prediction of Attribute Economic Importance Segments

Ecological Product Attribute	Wilks' Lambda	F	df1	df2	Sig.
Energy Requirements	0.557	78.653	1	99	0.000
Water Usage	0.691	44.321	1	99	0.000
Conversion Efficiency	0.726	37.331	1	99	0.000
Recyclability of product components	0.807	23.628	1	99	0.000
Regulatory compliance cost	0.942	6.142	1	99	0.015
Tool disposal cost at end of useful life	0.795	25.552	1	99	0.000
Product packaging	0.734	35.950	1	99	0.000
Upgrade-ability (lifecycle extension)	0.859	16.250	1	99	0.000
Full disclosure for materials of concern	0.831	20.190	1	99	0.000
Product take-back free or at minimal charge	0.745	33.881	1	99	0.000

Table 23: Test of Equality of Importance Segment Attribute Means

Structure Matrix for Attribute Importance	Function 1
Energy Requirements	0.64
Water Usage	0.48
Conversion Efficiency	0.44
Product packaging	0.43
Product take-back free or at minimal charge	0.42
Tool disposal cost at end of useful life	0.37
Recyclability of product components	0.35
Full disclosure for materials of concern	0.32
Upgrade-ability (lifecycle extension)	0.29
Regulatory compliance cost	0.18
Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions Variables ordered by absolute size of correlation within function.	

Table 24: Structure Matrix for Attribute Economic Importance Perceptions

In Table 24 above, only regulatory compliance cost is much below the good-predictor threshold of 0.3; this is aligned with earlier results in Table 7 that show all users believe focusing on regulatory compliance cost reduction is the least useful way of enabling ecologically sustainable development.

In summary, the two market segments differ in terms of their current perceptions of ecological product attributes economic importance, and this difference is statistically significant and theoretically meaningful. Ecological attribute importances provided a practical way for predicting which group a particular customer might be belongs to. The segmentation utility is effective since the discriminant function achieved a 96% hit ratio. Finally, determinant attributes ascertained in Table 24 show items related to efficient use and resource conservation seem to have a clear relative importance, which is consistent with industry perspective and efforts for decades (Worth 2006).

SEGMENT PROFILES

Perception of the extent of environmental regulations is logically hypothesized to predetermine perceptions of economic importance of ecological product attribute. In this exploratory research, there is no existing empirical evidence of such influence; hence the difference between segment perceptions of regulations is tested. Survey respondents were asked to provide their perceptions of the regulatory environment where they operate on a scale of 0 (non existent) least to 10 (extensive). T-test results in Table 25 illustrates that is not the case and although the 2 segments differ significantly on their perception of economic importance of ecological attributes, they do not have a statistically significant difference in their perceptions of their respective regulatory requirements.

	Segment	N	Mean	Std. Deviation	Std. Error Mean
Regulatory Requirements	1	44	7.1364	1.7991	0.2712
	2	57	7.4035	1.9718	0.2612

Independent Samples Test
t-test for Equality of Means

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Regulatory Requirements	-0.701	99	0.485	-0.267	0.381

Table 25: T-Test Results For Two-Cluster Regulatory Requirements

In addition to regulatory perceptions, there were a few variables that did not reveal statistically significant differences between segments:

- Perceptions regarding the reduction of ecological impact
- Company size in terms of sales and number of employees
- Perceptions of ecological footprint reduction know-how

In addition to the statistically significant differences in how the 2 segments view the economic importance of ecological product attributes shown in Table 19, the segments did show statistically significant and meaningful differences on several other variables. The Eco-Proactive segment places a heavy emphasis on minimizing their ecological footprint sufficiently so that future regulations are not deemed necessary, which implies the segment is taking a relatively aggressive approach that can reduce ecological impact while simultaneously trying to reduce future regulatory compliance cost structure.

A better understanding of this difference is afforded by a examining the difference found in how respondents in each segment indicated their companies' view of the ecological sustainability trend in terms of being a cost or an opportunity. The Eco-Proactive segment showed almost 10% higher frequency of responses that view the trend as an opportunity, which indicates a perception of a higher sense of control over the trend than the Cost-Centric segment (Chattopadhyay, Glick *et al.* 2001). That control perception may partially explain the aggressive approach to reducing ecological impact and the attempt to direct their resources towards an externally oriented action; attempting to influence regulations (Flannery and May 2000; Chattopadhyay, Glick *et al.* 2001).

A third variable that showed a meaningful difference is the percentage of each segment's production that is made for company-branded devices (i.e. captive) versus devices made for other companies and sold under non-company brands. Eco-Proactive companies showed a higher frequency of manufacturing their own brands; they have higher name recognition than Cost-Centric companies that make products mostly for other company brands.

Finally, Cost-Centric respondents had a lower average of industry tenure of 14.8 years versus the Eco-Proactive segment's 17.23 years. This longer experience may explain the sense of control asserted above as a characteristic of the Eco-Proactive segment, but no clear conclusions can be made based on this difference since although it exists, it was not statistically significant at 0.05. Table 26 below summarizes the differences between Eco-Proactive and Cost-Centric segments.

VARIABLE	Cost-Centric	Eco-Proactive
Economic Importance of Ecological Attributes	Low	High
Sustainability View	Cost (61.4%) Opportunity (38.6%)	Cost (52.7%) Opportunity (47.3%)
Ecological Leadership	Low Emphasis	High Emphasis
Captive Capacity	38.8%	50.2%
Years in Industry	14.8	17.2

Table 26: Differences Between Cost-Centric and Eco-Proactive Segments

In summary, segmentation based on perceptions of ecological attribute economic importance improves the ability of belief to predict customer intentions and helps avoid making the wrong inferences. The semiconductor market can be segmented into Eco-Proactive and Cost-Centric groups that differ significantly based on objective and subjective criteria as illustrated above. Upcoming results related to the first research question concerning belief's relationship with intentions will be tested for each segment separately.

RESULTS RELATED TO THE FIRST RESEARCH QUESTION

At this point, since reliable and valid scales that measure the belief and attitude constructs have been established and the market has been segmented on the basis of economic importance of the attributes in the belief scale, the research hypotheses can be tested to address the research questions.

The first research question is concerned with addressing the relationship between belief about ecological attributes usefulness and user intentions in each segment. Two behavioral intentions (product adoption and joint R&D cooperation) are considered and there are two segments, hence the two related hypotheses will be tested for each segment; a total of 4 hypotheses will be tested to address the first research question.

Hypothesis 1a:

> Belief about the usefulness of ecological product attributes in each segment is positively related to the segment's intentions to include the ecological impact of products in their new product adoption decision process.

Hypothesis 1b:

> Belief about the usefulness of ecological product attributes in each segment is positively related to the segment's intentions to form cooperative relationships with suppliers that focus on reducing ecological impact.

Multiple regression analyses will be used test the hypotheses. The purpose is to establish predictive association between the belief construct factors and the customer behavioral measures representing their intentions to include ecological impact of products in their mid-term (2-5 years) trial evaluations preceding new product adoptions, and intentions to form cooperative agreements in which they engage with equipment suppliers in long-term (5-15 years) joint R&D.

It is assumed the relationships being examined between all variables are linear, and the least square method will be used to fit the straight line to the data. All independent variables are measured using the same scale, data is assumed to come from normally distributed populations, and error terms are independent and distributed normally (Hair, Babin *et al.* 2003).

THE ASSOCIATION BETWEEN BELIEF AND CUSTOMER INTENTIONS

To test hypotheses H1a and H1b, belief factors are used simultaneously as independent variables in multiple regression analysis with each dependent behavioral intention variable; this will help account for the fact that all factors are usually at play simultaneously. As a reminder before presenting the results, the Cost-Centric segment has a "low" perception of ecological attributes current economic importance and Eco-Proactive segment has a "high" perception of importance.

As shown in Table 27, no significant relationship was found between the Eco-Centric segment's ecological belief and their intentions to include ecological product attributes in deciding which products to trial test. Therefore Hypothesis 1a is rejected for this segment.

Model Summary					
R	R Square	Adjusted R Square	Std. Error of the Estimate		
Cost-Centric					
0.329	0.108	0.034	1.210		
ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.404	3	2.135	1.46	0.242
Residual	52.696	36	1.464		
Total	59.100	39			
Dependent Variable: TRIAL EVALUATION INTENTION					
Selecting only cases for which GROUP = Cost-Centric					
Coefficients	Unstandardized		Standardized	t	Sig.
	B	Std. Error	Beta		
(Constant)	4.663	0.200		23.3	0.000
b_operat	0.295	0.190	0.245	1.56	0.128
b_rsourc	-0.183	0.203	-0.143	-0.9	0.373
b_law	0.178	0.200	0.141	0.89	0.379

Table 27: Relation Between Belief and Cost-Centric Trial Intentions

A significant relationship was found between the Eco-Proactive segment's belief and intentions to include ecological product attributes in deciding which products to trial test. Therefore Hypothesis 1a is supported for this segment and the results are presented in Table 28. The multiple coefficient of determination (R^2) is small but the overall relationship is statistically significant. The small size of R^2 is not surprising due to the fact equipment selection for trial testing is influenced by a multitude of process and performance factors that are not considered in this research.

Individual factor regression coefficients demonstrate that factors associated with reducing the ecological impact of manufacturing operations and efficient use of natural resources are consequential and significant predictors positively related to the trial testing intentions. The factor associated with legal compliance is not a significant predictor; possibly due to the fact legal compliance is assumed as a minimum requirement.

Model Summary					
R	R Square	Adjusted R Square	Std. Error of the Estimate		
Eco-Proactive					
0.410	0.168	0.110	1.045		
ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	9.488	3	3.163	2.89	0.046
Residual	46.980	43	1.093		
Total	56.468	46			
Predictors: (Constant), b_law for analysis 1, b_rsourc for analysis 1, b_operat for analysis 1					
Dependent Variable: TRIAL EVALUATION INTENTION					
Selecting only cases for which GROUP = Eco-Proactive					
Coefficients	Unstandardized		Standardized	t	Sig.
	B	Std. Error	Beta		
(Constant)	5.010	0.158		31.70	0.000
b_operat	0.372	0.177	0.301	2.10	0.042
b_rsourc	0.299	0.145	0.290	2.06	0.045
b_law	0.198	0.181	0.156	1.09	0.281

Table 28: Relation Between Belief and Eco-Proactive Trial Intentions

A significant relationship was found between the Cost-Centric segment's belief and intentions to seek out joint technology development partners on the basis of their attention to reduce the ecological impact of their products. Therefore Hypothesis 1b is supported for this segment and the results are presented in Table 29. Once again, the multiple coefficient of determination (R^2) is expectedly small but the overall regression model is statistically significant.

Individual factor regression coefficients shown in Table 29 demonstrate that only the factor associated with reducing the ecological impact of manufacturing operations is a significant predictor and positively related to long-term cooperation intentions. Factors associated with efficient use of natural resources and legal compliance are not significant predictors.

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
Cost-Centric			
0.44	0.20	0.13	1.21

Predictors: (Constant), b_law for analysis 1, b_operat for analysis 1, b_rsourc for analysis 1

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	12.78	3	4.258	2.93	0.047
Residual	52.32	36	1.453		
Total	65.1	39			

Dependent Variable: INTENTION TO SEEK JOINT R&D ECOLOGICAL PARTNERS
Selecting only cases for which GROUP = Cost-Centric

Coefficients	Unstandardized		Standardized	t	Sig.
	B	Std. Error	Beta		
(Constant)	4.701	0.199		23.57	0.000
b_operat	0.445	0.189	0.352	2.35	0.024
b_rsourc	-0.340	0.202	-0.253	-1.68	0.101
b_law	-0.020	0.200	-0.015	-0.10	0.920

Table 29: Relation Between Belief and Cost-Centric Cooperation Intentions

As shown in Table 30, no significant relationship was found between the Eco-Proactive segment's belief and intentions to seek out joint technology development partners on the basis of their attention to reducing ecological impact of their product. Therefore Hypothesis 1b is rejected for the Eco-Proactive segment.

Model Summary					
R	R Square	Adjusted R Square	Std. Error of the Estimate		
Eco-Proactive					
0.19	0.04	-0.03	1.44		
ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.32	3	1.106	0.53	0.664
Residual	89.66	43	2.085		
Total	92.98	46			
Dependent Variable: INTENTION TO SEEK JOINT R&D ECOLOGICAL PARTNERS					
Selecting only cases for which GROUP = Eco-Proactive					
Coefficients	Unstandardized		Standardized	t	Sig.
	B	Std. Error	Beta		
(Constant)	4.925	0.218		22.56	0.000
b_operat	0.057	0.244	0.036	0.23	0.816
b_rsourc	0.237	0.201	0.179	1.18	0.244
b_law	-0.121	0.251	-0.075	-0.48	0.631

Table 30: Relation Between Belief and Eco-Proactive Cooperation Intentions

Longer-term cooperative R&D relationships seem more illusive than the more immediate trial evaluation intentions. This maybe due the fact the industry experiences fairly radical technological advancement every few years that make many established suppliers irrelevant and previously unknown new comers very relevant. The fact the Cost-Centric seems interested in long-term cooperation may be an indication of an attempt to "out-source" ecological issues. More interpretation discussion is in Chapter 5.

Results of testing the four hypotheses demonstrate that the relationship between belief about the usefulness of ecological product attributes and customer intentions varies based on both which segment is being examined and the time horizon associated with the intentions.

For the Eco-Proactive segment, their belief about ecological usefulness is related to their intention to include them in upcoming trial evaluations. They seem ready to act in the near future. For the Cost-Centric segment, their belief about ecological usefulness is related to their intention to form long-term cooperative agreements to address ecological attributes. They seem to want to "outsource" ecological issues.

This is useful for a company that focuses on improving the ecological attributes of its products. It can approach customers in either segment with a targeted message that is aligned with the customer current perceptions economic importance of ecological product attributes.

RESULTS RELATED TO THE SECOND RESEARCH QUESTION

A reliable and valid scale that measures the users ecological concern attitude construct has been established and is used to test research hypotheses related to the second research question.

The second research question is related to assessing the relationship between users concern about the environment and their product adoption and joint R&D cooperation intentions. The two related hypotheses are restated below.

Hypothesis 2a:

Ecological concern attitude towards the environment is positively related to user intentions to include the ecological impact of products in their new product adoption decision process.

Hypothesis 2b:

Ecological concern attitude towards the environment is positively related to user intentions to form cooperative relationships with suppliers that focus on reducing ecological impact.

Using the same approach and variable assumptions as the ones for the first research question, multiple regression analyses will be used test the hypotheses. The purpose is to establish predictive association between the ecological concern construct factors and the customer behavioral intention measures.

THE ASSOCIATION BETWEEN ECOLOGICAL CONCERN AND CUSTOMER INTENTIONS

Multiple regression analysis are used to assess how users ecological concern (attitude) is related to their two behavioral intentions. To test hypotheses H2a and H2b, ecological concern factors are used simultaneously as independent variables in multiple regression analysis with each of the two dependent intention variables.

A significant relationship was found between ecological concern and intentions to include ecological product attributes in deciding which products to trial test. Therefore Hypothesis 2a is supported. Results that support acceptance of Hypothesis 2a are presented in Table 31. Similar to the significant belief relationships, the multiple coefficient of determination (R^2) is small but the overall model relationship is statistically significant.

Regression coefficients for individual factors demonstrate that factors associated with personal attitude and behavior, attitude towards an individual company's business practices, and the general attitude that avoiding pollution is an optimal approach are consequential and significant predictors positively related to a company's intention of including a supplier in trial evaluations.

The factor associated with attitude towards the industry's collective responsibility is not a significant predictor. This may indicate a collective attitude that the industry is sufficiently active in addressing ecological issues, which is also aligned with the belief that the industry's ecological problems are not exaggerated as shown in Table 8.

Model Summary						
R	R Square	Adjusted R Square	Std. Error of the Estimate			
0.381	0.145	0.112	1.111			
ANOVA						
	Sum of Squares	df	Mean Square		F	Sig.
Regression	21.416	4	5.354		4.33	0.003
Residual	125.986	102	1.235			
Total	147.402	106				
Dependent Variable: TRIAL EVALUATION INTENTION						
Coefficients	Unstandardized		Standardized		t	Sig.
	B	Std. Error	Beta			
(Constant)	4.925	0.107			45.84	0.000
C_PERSNL	0.263	0.108	0.223		2.43	0.017
C_INDUST	0.149	0.108	0.126		1.38	0.171
C_BUSINS	0.224	0.108	0.190		2.08	0.040
C_AVOID	0.246	0.108	0.209		2.28	0.025

Table 31: Relation Between Attitude and Trial Evaluations Intentions

As shown in table 32, no significant relationship was found between ecological concern and intentions to seek out joint technology development partners on the basis of their attention to reducing ecological impact of their product. Therefore Hypothesis 2b is rejected.

Model Summary						
R	R Square	Adjusted R Square	Std. Error of the Estimate			
0.260	0.068	0.031	1.335			
ANOVA						
	Sum of Squares	df	Mean Square		F	Sig.
Regression	13.188	4	3.297		1.85	0.13
Residual	181.878	102	1.783			
Total	195.065	106				
Dependent Variable: INTENTION TO SEEK JOINT R&D ECOLOGICAL PARTNERS						
Coefficients	Unstandardized		Standardized		t	Sig.
	B	Std. Error	Beta			
(Constant)	4.907	0.129			38.01	0.000
C_PERSNL	0.125	0.130	0.092		0.97	0.336
C_INDUST	0.131	0.130	0.096		1.01	0.316
C_BUSINS	0.162	0.130	0.120		1.25	0.214
C_AVOID	0.256	0.130	0.188		1.97	0.052

Table 32: Relation Between Attitude and Cooperation Intentions

Acceptance of Hypothesis 2a and rejection of 2b demonstrates that attitude toward the natural environment, in the sense of concern about ecological consequences, is positively related to inclusion in the more immediate trial evaluations and not to longer-term cooperation. The lack of significant relationships with longer-term intentions is likely explained in a similar fashion as in the first research question above. The attitude-intention relationship results are similar to the belief-intentions results for the Eco-Proactive market segment.

RESULTS RELATED TO THE THIRD RESEARCH QUESTION

Belief and attitude factors were used to test the research hypothesis related to the third research question assessing the relationship between customers' belief about ecological attribute usefulness and their concern about the environment. The related hypothesis is restated below.

Hypothesis 3:

Ecological belief about the utility of ecological product attributes is positively related to ecological concern.

Pearson correlations were examined to assess the linear associations between the metric belief and attitude factors in terms of their presence, strength, and direction. Similar to the regression analyses above, relationships between all variables are assumed to be linear, the least square method will be used to fit the straight line to the data, all independent variables are measured using the same scale, sample data is assumed to come from normally distributed populations, and error terms are independent and distributed normally.

The difference in this analysis is that each belief factor will be correlated with each attitude factor at a time; correlations analysis are the same as bivariate regression (Hair, Babin *et al.* 2003) and therefore are subject to the same assumptions. Some correlation was expected since both constructs are partially related to the behavioral variables as demonstrated above.

THE ASSOCIATION BETWEEN BELIEF AND ATTITUDE

Pearson correlations are utilized to assess how factors that make up users belief about ecological attribute usefulness is related to factors that make up their ecological concern.

Table 33 below shows that a third of the correlations are significant. Each belief factor has a small but definite relationship with a different attitude factor. Only three out of the twelve possible relationships are positive and significant at the 0.05 level and two are positive and significant at 0.1. One relationship is negative and significant at 0.05. Therefore Hypothesis 3 is only mostly not supported.

Correlations		C_PERSNL	C_INDUST	C_BUSINE	C_AVOID
B_OPERAT	Pearson Correlation	0.012	0.348	-0.097	0.165
	Sig. (2-tailed)	0.911	**0.001**	0.356	0.116
B_RSOURC	Pearson Correlation	0.293	-0.315	0.081	-0.113
	Sig. (2-tailed)	**0.005**	**0.002**	0.441	0.284
B_LAW	Pearson Correlation	0.069	0.089	0.283	-0.177
	Sig. (2-tailed)	0.515	0.400	**0.006**	0.092

Table 33: Correlation Between Belief and Attitude.

Personal attitude and behavior has positive relationship with the belief that efficient use of natural resources will lead to sustainable industry growth. A similar relationship exists between the attitude towards industry's collective responsibility of reducing ecological impact and the belief that reducing ecological impact of manufacturing will lead to sustainable growth. The remaining positive relationship was between attitude towards a company's practices and the belief that regulations will help achieve sustainability.

There is a significant negative relationship between the attitude towards industry's collective responsibility and the belief that resource conservation is key to sustainable development. There is no readily plausible explanation of this correlation. However this attitude factor was the only one without a significant predictor relationship with intentions in the regression models used to answer the second research question, indicating industry's collective responsibility is not a factor in decision making.

The fact significant correlations were not found between all belief and attitude factors supports the need to use both belief and attitude as different constructs when examining their relationship with behavior. In other words, as mentioned in the literature review section pertaining to attitude theory and cognitive structure, researcher seeking a more comprehensive understanding of behavioral intentions should measure it along with both their belief and attitude.

RESULTS RELATED TO THE FOURTH RESEARCH HYPOTHESIS

In line with the exploratory nature of this research and the general presentation of attitude constructs in the literature as a learned predisposition, the relationship between ecological knowledge and ecological concern is tested. However, before embarking on such a test, the ecological knowledge scale used was only partially validated in consumer contexts and not an industrial one.

Hence, as described in the following subsection, the knowledge scale will undergo the same purification procedures applied to the belief and attitude scales and the measure purification procedures explained in the construct unidimensionality section were applied to the knowledge scale.

THE ECOLOGICAL KNOWLEDGE CONSTRUCT

The initial EFA 3-factor solution had two items, K_VOC and K_ENERGY, load on 2 factors at >0.5, hence they were removed. The subsequent EFA solution produced a 3-factor simple structure that explained 70.94% of variance, had a Cronbach's alpha of r=0.921, and all factors had eigenvalues >2.6. The factors could be logically named as one is related to knowledge about industry ecological issues, and the other two factors are related to general knowledge about specific ecological issues, and high-level issues.

The 14-item measurement model was tested using CFA and the resulting model fit was marginal (Normed X^2=4.43/df, p=0.00, RMSEA=0.11, NFI=0.93, NNFI=0.95, CFI=0.96). The item K_GRNHSG had the lowest pattern coefficient and therefore was removed. A 3-factor simple structure was produced by EFA using the remaining 13 items which explained 71.13% of total variance, had an alpha r = 0.915 and eigenvalues >2.49. The CFA model fit results for the re-specified 13-item scale showed a slight improvement, but not sufficient fit (Normed X^2=4.03/df, p=0.00, RMSEA=0.11, NFI=0.93, NNFI=0.95, CFI=0.96).

The lowest pattern coefficient was K_ACIDRN and it was removed to generate a re-specified 12-item scale. At this point, and consistent with the general approach of considering more than one way of re-specifying the measurement model, a comparison between the above option of removing K_ACIDRN and K_GLOBLZ, which in SPSS loaded almost at 0.5 on a second factor, suggested that the K_ACIDRN choice would produce a slightly better solution in terms of explaining total variance hence it was selected.

EFA of the 12 remaining items produced a simple 3-factor structure that explained 71.7% of total variance, had eigenvalues greater than 2.3, and an alpha of r=0.91. The factor solution showed K_GLOBLZ loaded at >0.45 on a second factor, however at this point it will be kept in order to further examine the CFA for of the 12-item measurement scale, which produced a slightly worst fit (Normed X^2=4.51/df, p=0.00, RMSEA=0.12, NFI=0.93, NNFI=0.95, CFI=0.96). Therefore the item K_ACIDRN was put back in and K_GLOBLZ was removed to determine if this new list of 12 items (designated 12ItemA in software data to eliminate confusion) will result in better model fit.

The new 12 items EFA produced a similar 3-factors simple structure that explained 71.86% of total variance, had eigenvalues greater than 2, and alpha of r=0.91 and a slightly better CFA model fit (Normed X^2=3.7/df, p=0.00, RMSEA=0.10, NFI=0.94, NNFI=0.96, CFI=0.97). However K_ACIDRN once again showed the lowest pattern coefficient in LISREL and K_CHMPOL was a low loader on one factor in SPSS at 0.516 and a relatively high loader on a second factor at 0.476. So the effect of the removal of K_ACIDRN and K_CHMPOL individually was assessed to determine the more appropriate deletion to specify next measurement model to be tested.

Removing K_ACIDRN deteriorated the total variance explained by a relatively large 6 percentage points, while removing K_CHMPOL improved it by 2 points, hence it was decided that the next 11-Item Knowledge measure re-specification will be achieved by removing K_CHMPOL. The EFA produced a similar 3-factor solution that explained 73.23% of total variance, had eigenvalues >1.7, and alpha of r=0.90. The CFA of the 11-item measurement model resulted in a slightly better fit (Normed X^2=3.59/df, p=0.00, RMSEA=0.10, NFI=0.94, NNFI=0.96, CFI=0.97). K_ACIDRN once again had the lowest pattern coefficient in the path diagram; hence it was removed to specify the next 10-item measurement scale.

EFA of the 10-item scale produced a simple structure 2-factor solution that basically combined the two general knowledge factors in previous solutions into one general knowledge factor and maintained a factor related to industry knowledge. The 2-factor solution explained 65.18% of variance, had eigenvalues >2.8, and alpha of r=0.89. The CFA showed an improved, and acceptable, model fit (Normed X^2=3.55/df, p=0.00, RMSEA=0.09, NFI=0.95, NNFI=0.97, CFI=0.97).

Although acceptable scale validity is achieved using the 10 items, and consistent with the general approach used throughout the measure purification efforts for all constructs, the removal of alternative scale items was investigated to assess if a better measurement scale can be achieved. The first such eliminations included the item with lowest loading (K_NUCLAR) to test the resulting 9-item scale, where the EFA produced a similar 2-factor solution that explained 67.4% of variance, had Eigen values >2.5, and alpha of r=0.879, but it deteriorated the CFA model fit noticeably (Normed X^2=4.95/df, p=0.00, RMSEA=0.13, NFI=0.93, NNFI=0.93, CFI=0.95). Alternatively, K_NUCLAR was put back in the scale and K_HAZSHP was removed due to having the lowest pattern coefficient in the 10-Item CFA solution. The new 9-item scale (designated 9-ItemA in the software) improved fit slightly but not as good as the 10 item measure (Normed X^2=4.48/df, p=0.00, RMSEA=0.11, NFI=0.94, NNFI=0.95, CFI=0.96).

The 10-item scale will be retained as the most reliable and valid measurement instrument of the Knowledge construct based on the EFA and CFA results discussed above.

Table 34 illustrates the knowledge construct's factor structure, factor loadings of each attribute, and attribute items making up each factor. Two dimensions represent knowledge about ecological issues:

1. Specific knowledge about ecological issues affecting industry (K_INDUST).
2. General knowledge about ecological issues (K_GENERL)

There was no a prior expectation of the factor structure, however the robust simple factor structure, with logical and meaningful factors, lends conceptual validity to the knowledge construct. Statistical results that demonstrate empirical validity and reliability are shown in Table 35, with one minor violation of pre-determine criteria but acceptable for this purpose.

Individual factor contributions to explaining the total variance are shown in Table 36. The two factors related to resource efficiency and reducing the ecological impact of operations explain half of the variance. Figure 8 presents the path diagram of knowledge's 2 underlying dimensions, and Table 37 provides fuller descriptions of the ecological knowledge factors.

Rotated Component Matrix		Component	
Ecological Issue Knowledge Statement		K_INDUST	K_GENERL
Full environmental cost accounting	K_ACOUNT	0.87	
Environmental Management Systems (EMS)	K_EMS	0.85	
Hazardous Waste Disposal and Landfill restrictions	K_WASTE	0.79	
International transport of hazardous wastes	K_HAZSHP	0.79	
Resource conservation methods, tools, and costs	K_CONSRV	0.73	
Climate change (i.e. global warming)	K_GLBWRM		0.84
Ozone atmospheric layer depletion over Antarctica	K_OZONE		0.80
World population growth	K_POPGRO		0.69
Industrial pollution of water resources and soil	K_H2OPOL		0.66
Radiation from storage of nuclear waste	K_NUCLAR		0.53
Extraction Method: Principal Component Analysis.			
Rotation Method: Varimax with Kaiser Normalization.			

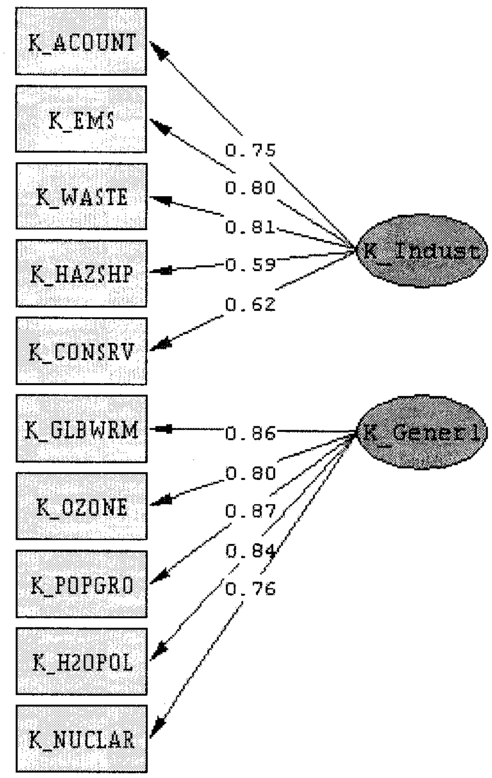
Table 34: Knowledge Construct's Factors Structure and Loadings

Exploratory Factor Analysis	**Criteria**	**Result**
Eigenvalue	>1	>2.8
Item's Factor Loading	>0.5	>0.53
Item not loading on multiple factors	Yes	Yes
Total Variance explained	>60%	65.2%
Reliability (Cronbach's Alpha)	>0.7	0.8879
Confirmatory Factor Analysis		
Measures of Absolute Fit		
Significant Likelihood-Ratio Chi-Square Statistic (X^2)	<0.05	0
Root Mean Square Error of Approximation (RMSEA)	<0.08	0.09
Incremental Fit Measures		
Normed Fit Index (NFI)	>0.9	0.95
Tucker-Lewis Index (TLI or NNFI)	>0.9	0.97
Parsimonious Fit Measures		
Normed Chi-squared (X^2/Degrees of Freedom)	1 to 5	3.55
Comparative Fit Index (CFI)	>0.9	0.97

Table 35: Knowledge Construct Validity and Reliability Results

Total Variance Explained - Rotation Sums of Squared Loadings			
Component	Total	% of Variance	Cumulative %
K_INDUST	3.67	36.73	36.73
K_GENERL	2.84	28.45	65.18

Table 36: Knowledge Factors Contribution to Variance Explanation



Chi-Square=120.81, df=34, P-value=0.00000, RMSEA=0.092

Figure 8: Knowledge Confirmatory Factor Analysis Path Diagram

K_INDUST	**Specific knowledge about ecological issues affecting industry**
	Hazardous Waste Disposal and Landfill restrictions
	Resource conservation methods, tools, and costs
	Full environmental cost accounting
	Environmental Management Systems (EMS)
	International transport of hazardous wastes
K_GENERL	**General knowledge about ecological issues**
	Industrial pollution of oceans, rivers, air, soil (including erosion), drinking water, and groundwater
	Climate change (i.e. global warming)
	Ozone atmospheric layer depletion over Antarctica
	Radiation from storage of nuclear waste
	World population growth

Table 37: Descriptions of Knowledge Factors Related to Ecological Issues

THE ASSOCIATION BETWEEN KNOWLEDGE AND ATTITUDE

Validated ecological knowledge and concern scales will be used to test the fourth research hypothesis pertaining to the relationship between customers' knowledge about ecological issues and their concern about the environment. The fourth hypothesis is restated below.

Hypothesis 4:

> Perceived ecological knowledge of users is positively related to their ecological concern attitude towards the environment.

Pearson correlations are utilized to assess how users' knowledge about ecological issues is related to their ecological concern (attitude); each construct will be represented by its underlying factors. All variable assumptions are the same as the ones used in the previous correlation analysis used to test the third research hypothesis.

Table 38 below shows that Hypothesis 4 cannot be supported. None of the factors were related at the 0.05 significance level and only one of eight possible relationships was significant at the 0.1 level. A possible explanation of the this outcome may be related to target respondents are all relatively very highly educated and their level of knowledge is uniformly high, making the typical variations in consumer type research non existent in this particular case. Also reducing variation is the highly specific nature of semiconductor manufacturing; all respondents having a similar technical ilk.

Table 39 shows that most respondents posses a graduate degree (56%), and the vast majority of over 96% have college degrees.

Correlations			
		K_INDUST	K_GENERL
C_PERSNL	Pearson Correlation	0.012	0.169
	Sig. (2-tailed)	0.901	0.085
C_INDUST	Pearson Correlation	-0.091	0.115
	Sig. (2-tailed)	0.358	0.246
C_BUSINS	Pearson Correlation	0.135	0.075
	Sig. (2-tailed)	0.170	0.452
C_AVOID	Pearson Correlation	0.058	-0.096
	Sig. (2-tailed)	0.561	0.334
Listwise N=104			

Table 38: Correlation Between Knowledge and Attitude Factors

	EDUCATION	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some College	4	3.4	3.5	3.5
	College Degree	46	39.7	40.7	44.2
	Graduate Degree	55	47.4	48.7	92.9
	PhD	8	6.9	7.1	100
	Total	113	97.4	100	
Missing	System	3	2.6		
Total		116	100		

Table 39: Respondents' Education Level

To further examine the surprising lack of correlation between knowledge and attitude factors, the relationship was for each of the market segments. Only one correlation was significant at the 0.05 level for the Cost-Centric segment (between attitude towards business practices and industry knowledge R=0.33, sig.=0.04) and one at 0.1 level for the Eco-Proactive segment (between personal attitude and general knowledge R=0.26, sig.=0.06). These results do not provide sufficient support and therefore the fourth hypothesis is rejected.

RESULTS RELATED TO DEMOGRAPHIC VARIABLES

Several variables were included in the survey to support the exploratory nature of this research. Variables representing respondent company revenues, company size in terms of the number of employees, individual executive status, level of involvement in equipment procurement decisions, and years of experience in the industry are used to better understand the two behavioral intention variables and perform some validation checks.

In cases where the 2 variables being compared are metric, the Pearson correlations will be examined under the same conditions used for Hypotheses three and four. In cases where one of the variables is ordinal or nominal (non-metric) the Spearman Rank Order Correlation (rho) measurements will be used. The Spearman correlation coefficient typically results in lower correlations and is considered a more conservative statistic, however it is necessary in cases where non-metric variables are being examined to avoid making the wrong inferences (Hair, Babin *et al.* 2003).

As illustrated in the survey in Appendix A, the 2005 sales revenues and company size were ordered in such a way that selecting a smaller number means a larger response. For example selecting 0, the lowest sales selection option, indicates the largest 2005 revenue of over $10 billion, and selecting 0 for size indicates the highest number of employees over 5000. Whereas selecting 4, the highest sales selection option, indicates the smallest 2005 revenues of <$500 million, and so on. This is important for interpretation.

INTENTIONS TO CONSIDER ECOLOGY IN TRIAL SELECTION

The users' intentions to consider ecological impact when deciding which new equipment to put through the trial tests did not show any significant correlations with executive status or years of experience.

However significant correlations were found with the three other variables. Table 40 shows that small but significant relationships were found with sales revenues and company size. Due to the coding scheme explained above, the negative correlations are interpreted as the larger the company and higher its sales revenues the more likely its will consider ecological impact in trial selection decisions. Also, there is a moderate and significant relationship between the level of the respondent's involvement in decision-making and the intention to consider ecological consequences in trial selections.

This is a consequential finding for equipment suppliers since it suggests that decision makers in larger companies are likely to consider the ecological impact of their product(s) when deciding on their inclusion in upcoming trials; minimizing that impact potentially provides them with a relative advantage.

	Spearman's rho	SALES – 2005 Revenues
TRIAL	Correlation Coefficient	-0.26
Listwise N = 108	Sig. (2-tailed)	0.01
		SIZE – No. Of Employees
TRIAL	Correlation Coefficient	-0.25
Listwise N = 112	Sig. (2-tailed)	0.01
		Level of INVOLVEMENT
TRIAL	Correlation Coefficient	0.39
Listwise N = 113	Sig. (2-tailed)	0.00

Table 40: Intention to Include Ecology in Trial Selection and Demographic Variables

INTENTIONS TO CONSIDER ECOLOGY IN R&D COOPERATION

Customer intentions to consider ecological impact when seeking joint technology development partners did not show any significant correlations with demographic variables except the one related to the level of involvement.

Table 41 shows a moderate and significant relationship between the level of the respondent's involvement in decision-making and the intention to consider ecological consequences when seeking technology development partners.

This is a consequential finding for equipment suppliers since it suggests that decision makers in their customer base are likely to consider the ecological impact of their product(s) when selecting long term partners, hence it supports the finding in the above section that minimizing their products ecological impact could potentially provides them with an advantage.

	Spearman's rho	LEVEL OF INVOLVEMENT
R&D Cooperation	Correlation Coefficient	0.42
Listwise N = 113	Sig. (2-tailed)	0.00

Table 41: Intention to Include the Ecology in Cooperation and Demographic Variables

VARIOUS RESPONSE VALIDATIONS

Users that intend to include ecological impact in their equipment trial selection criteria would be expected to also seek technology partners that are actively working on reducing their ecological impact. Table 42 provides evidence that this is the case since the two metric dependent variables exhibit a strong and highly significant correlation.

Also, it would be logically expected that companies with high revenues would also have a large number of employees and visa versa. The strong correlation in Table 42 provides strong evidence of that expectation as well.

Finally, it would be expected the longer a respondent has worked in the industry the more likely she or he has achieved executive status. This was demonstrated by the small but significant correlation between the two variables. The negative sign is due to the designation of a 0 for executive status and a 1 for non-executive status in the survey. The small measurement of the correlation factor is likely due to the role talent level, experience, political savvy, and other variables play, which were not considered in this research.

		TRIAL
R&D Cooperation	Pearson Correlation	0.67
Listwise N=113	Sig. (2-tailed)	0.00
	Spearman's rho	SIZE - No. of Employees
SALES - 2005 Revenues	Correlation Coefficient	0.81
Listwise N = 107	Sig. (2-tailed)	0.00
	Spearman's rho	YEARS OF EXPERIENCE
EXECUTIVE STATUS	Correlation Coefficient	-0.26
Listwise N = 110	Sig. (2-tailed)	0.01

Table 42: Various Correlations for Response Validation

CHAPTER 5

CONCLUSION

SUMMARY

This exploratory research study was designed to develop a socioeconomic framework to address the ecological sustainability trend in the specific context of semiconductor manufacturing industry. Its primary purpose was achieved by developing scales that represent customer beliefs (about product attributes ecological usefulness) and attitudes (concern about the environment) and assessing their attitude-theory based predictive relationships with their behavioral intentions, which represented the market-based outcomes. Table 43 provides a summary of the hypothesis test results.

Two customer intentions that potentially offer suppliers a market-based advantage and economic benefits were considered to represent customer behavioral intentions. One is a mid-term intention of including ecological impact when deciding to select equipment for trial testing, a necessary step before adopting any product in an industrial decision-making process (Engel, Blackwell *et al.* 1986). The second is a long-term intention of seeking out technology development partners based on their efforts to reduce the ecological impact of their products (Cannon and Perreault 1999; Lapierre 2000).

Research Question 1

User Intention 1

	Belief	Belief
	Cost-Centric Segment	**Eco-Proactive Segment**
User Intention 1	**Belief Factors vs. Trial Inclusion**	**Belief Factors vs. Trial Inclusion**
	H1a_1: Positive Relation	**H1a_2: Positive Intention**
	Not Supported	**Supported**
	If non-significant model details are of interest please see Table 27	see table below

Multiple Regression	B	t	Sig
Reduced operations impact	0.372	2.10	**0.042**
Efficient use of natural resources	0.299	2.06	**0.045**
reduced regulatory compliance cost	0.198	1.09	0.281

	Cost-Centric Segment	Eco-Proactive Segment
User Intention 2	**Belief Factors vs. Cooperative R&D**	**Belief Factors vs. Cooperative R&D**
	H1b_1: Positive Relation	**H1b_2:Positive Relation**
	Supported	**Not Supported**
	see table below	If non-significant model details are of interest please see Table 30

Multiple Regression	B	t	Sig
Reduced operations impact	0.445	2.35	**0.024**
Efficient use of natural resources	-0.340	-1.68	0.101
reduced regulatory compliance cost	-0.020	-0.02	0.920

Research Question 2

User Intentions 1 & 2

	Ecological Concern	**Ecological Concern**
	Eco-Concern vs. Trial Inclusion	**Eco-Concern vs. Cooperative R&D**
	H2a: Positive Relation	**H2b: Positive Relation**
	Supported	**Not Supported**
	see table below	If non-significant model details are of interest please see Table 32

Multiple Regression	B	t	Sig
personal attitude and behavior	0.263	0.22	**0.017**
industry's collective responsibility	0.149	0.13	0.171
individual business practices	0.224	0.19	**0.040**
pollution avoidance is ideal	0.246	0.21	**0.025**

Research Question 3

Belief

	Ecological Concern	**Fourth Research Hypothesis**
	Eco-Concern vs. Belief	**Eco-Concern Vs. Eco Knowledge**
	H3: Positive Relation	**H4:Positive Relation**
	Correlation	Correlation
	Mostly Not Supported	**Not Supported**
	4 of 12 correlations are significant	0 of 8 correlations are significant

Table 43: Summary of Research Hypotheses Test Results

Another way of presenting a summary of the results is illustrated in Figure 9 that shows the significant predictor factors that have been confirmed in the context of the pre-study conceptual model depicted in Figure 1.

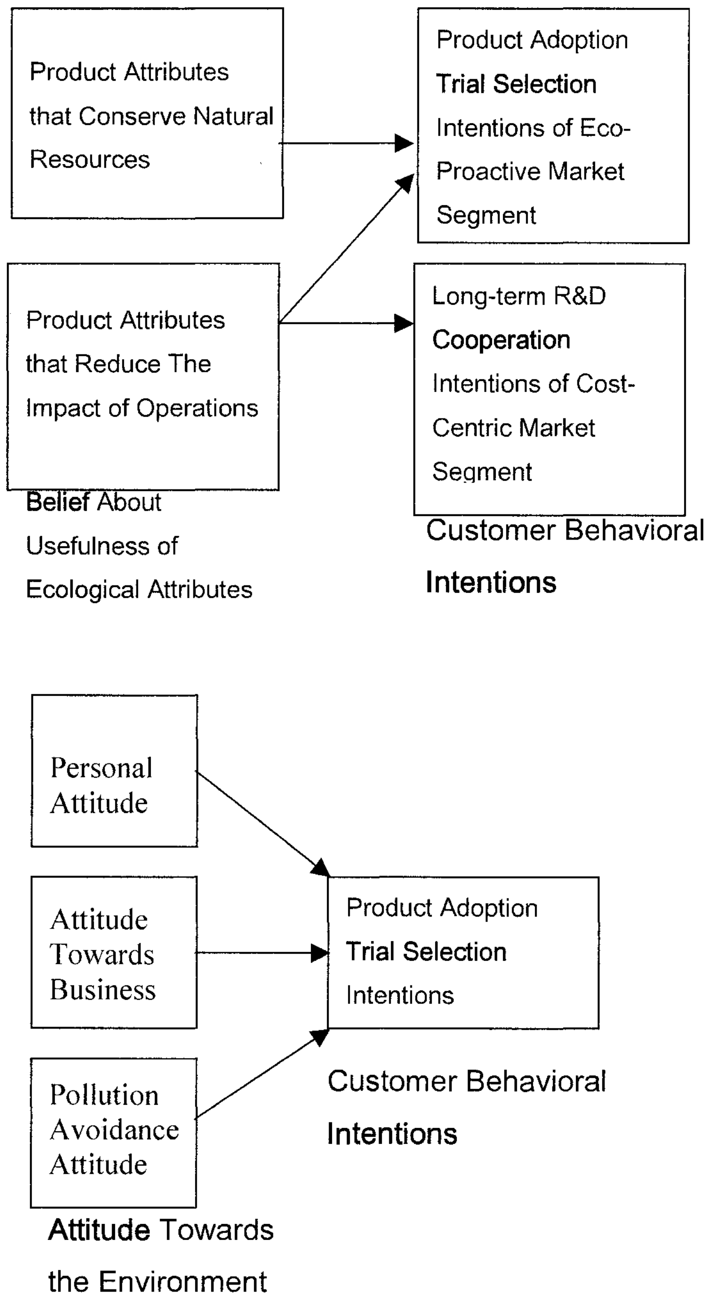


Figure 9: Confirmed Model Relationships in The Context of This Study

Reliable and valid ecological belief (about product ecological attributes usefulness) and ecological concern attitude constructs were developed in order to test their relationship with the dependent behavioral intention variables. This was accomplished conceptually and empirically. Conceptual validity was established via an extensive literature review that generated a comprehensive list of scale indicator items for each construct, and subsequently presenting the list to a multi-perspective research panel for face validity, clarity, appropriateness, and additional input. All items were included in an industry-wide survey that was used as the measurement instrument.

Empirical validity was established by using the survey responses to generate reliable and valid belief and attitude scales according to an extensive set of statistical criteria. The two largest semiconductor industry associations, who formally supported the research, sent out the industry survey and responses came from all global semiconductor-manufacturing hubs from companies that represented half of the entire global production capacity. Although it was only possible to send the survey once, non-response bias did not present a problem in the data set.

In addition to the economic aspects represented in the customer purchasing and cooperation intentions, the current economic importance of attribute items that made up the final belief construct were used as the basis for industry segmentation. This is necessary to avoid making the wrong inferences about the belief-behavior relationship. Two meaningful segments were found that had a “high” and a “low” perception of ecological attribute economic importance, hence belief-behavior relationships were tested separately for each segment.

KEY RESEARCH FINDINGS

SOCIOECONOMIC FRAMEWORK

Results of this study support the research model in Figure 1 as an appropriate initial socioeconomic framework to address the challenge of expanding the semiconductor industry while reducing its ecological impact. Socially oriented beliefs and attitudes are associated with economically oriented customer intentions.

The framework encompasses two economic aspects. One is concerned with potential economic gains by the equipment suppliers that are related to favorable industry behavior in response to suppliers reducing the ecological impact of their products. The other is related to the segmentation of the industry based on current economic evaluation models, which assists in the interpretation of the relationship between the belief and behavioral intentions variables.

The framework also encompasses two social aspects. An ecological concern attitude construct with a usable set of factors was established, and showed a statistically significant association with customer trial selection intentions. A set of factors representing the ecological utility belief construct was also established, and showed a similar association with trial selection intentions for the Eco-Proactive industry segments. The belief construct was also associated with the users cooperation intentions for the Cost-Centric segment.

ECOLOGICAL BELIEF AND ATTITUDE SCALES

The ability to empirically address the research questions and test the relationships in the Figure 1 conceptual model depended on the ability to establish reliable and valid measurement scales that represent the ecological belief and attitude constructs, which was accomplished in this research.

The construct representing beliefs about the usefulness of ecological product attributes has three underlying dimensions, or factors shown in Table 13, that are related to minimizing the ecological impact of manufacturing operations, maximizing the efficient use of natural resources, and minimizing the cost regulatory compliance. Found factor structure was similar to expectations described in the literature review regarding the ecological footprint attribute items; there was one exception related to the conversion efficiency attribute.

For the industry Eco-Proactive segment that placed high economic importance on ecological attributes, the two belief factors related to resource efficiency and reducing the ecological impact of operations explain half of the variance, and were both significant predictors of users' intentions of including ecological impact when deciding on which equipment to include in trial evaluations for subsequent product adoptions.

For the Cost-Centric industry segment that placed low economic importance on ecological attributes, the belief factor related to reducing ecological impact of operations was the only significant predictor of their intention to seek cooperative technology development relationships with suppliers focused on reducing ecological impact.

The fact that the belief factor related to reducing the ecological impact of operations was the only one to have predictive relationships with both user intentions, and explained the most variance, gave it an unexpected prominence that warrants an increased focus of the attribute items from which it is composed. This is consequential since, as demonstrated in Table 24, its attribute items are also predictive of market segments. Although the items related to the resource conservation factor had higher predictive ability of economic importance, all suppliers are addressing them due to their prominence (i.e. energy and water). Items related to operational impact are not readily obvious in their high relevance, and thus offer the potential to differentiate a product if a company is able to improve such attributes in addition to obvious resource conservation attributes.

The belief factor related to regulatory compliance explained 30% less variance and was not a significant predictor of any intentions of either segment. Also, its main item component of reducing compliance cost was not a predictor of economic importance based segments in Table 24. Focusing on regulation was believed to be the least useful item in achieving ecological sustainable industry growth as shown in Table 7.

The construct representing ecological concern attitude has four underlying dimensions (shown in Table 17) related to personal attitude, attitude towards industry's collective responsibility, attitude towards an individual firm's business practices, and a general attitude that showed a preference for avoiding pollution as an optimal way of addressing ecological concerns.

The relatively more subjective ecological concern scale did not have any dominating factors in terms of explaining the total variance. However, all factors except the one related to industry's collective responsibility were significant predictors of customer intentions to include ecological impact in deciding on which equipment to put through trial test evaluations.

The presence of predictive relationships between both belief and attitude constructs and users' intentions demonstrate the appropriateness of using cognitive structure as the basis of understanding and addressing socioeconomic issues, such as ecological sustainability, in a disciplined market-driven approach.

INDUSTRY SEGMENTS

Determination of how customers differ in their perceptions of ecological product attribute economic importances was made prior to using the research framework. If customers did not differ in their perceptions of attribute economic saliency, then such saliency would not need to be considered (Scott and Bennett 1971; Engel, Blackwell *et al.* 1986). However, since semiconductor customers can be segmented on such basis, belief and behavioral intention relationships were evaluated separately for each segment. This improves belief's predictive ability and avoids making the wrong inferences about such relationships (Scott and Bennett 1971; Sheth and Talarzyk 1972).

Analysis results showed that users could in fact be meaningfully segmented on the basis of attribute cost importance in current economic decision models. One segment had a high perception of economic importance (i.e. Eco-Proactive) and the other had a low perception of economic importance (i.e. Cost-Centric). The determinant attributes, attributes on which segments differ (Engel, Blackwell *et al.* 1986), are shown in Table 24, with the items related to natural resource conservation showing the most predictive power. Only regulatory compliance cost was not a helpful predictor on a multivariate basis.

There is useful insight from the segment profiles in Table 26. A marketer can assess which segment a user company falls into by gauging their perspective on ecological sustainability. If it is viewed as a cost, the user is likely in the Cost-Centric segment and the supplier can cultivate long-term relationships and position their offer of reducing ecological impact as a way of shifting the burden of addressing the ecology away from the user. Customers that have this perspective are likely to perceive some lack of control over the issue of ecological impact reduction (Chattopadhyay, Glick *et al.* 2001), and a supplier that approaches them with a long-term proposition is also assuring to this segment since relieving the time pressure is likely to encourage meaningful engagement.

If it is viewed as an opportunity, then the user is likely in the Eco-Proactive segment that emphasizes sustainable manufacturing and the supplier can use their superior ecological attributes to be included in upcoming trials tests. This segment likely perceives to have a good degree of control and approach the reduction of their ecological impact as a gainful opportunity worth the investment and innovation effort (Sharma 2000; Chattopadhyay, Glick *et al.* 2001).

In addition to improving the predictive ability of the belief construct, this segmentation scheme provides three more advantages. First, each segment can be targeted differently as shown by the results of the belief-behavior relationship assessment. The Eco-Proactive segment can be targeted for product inclusion in upcoming trials, and the Cost-Centric segment can be targeted to form long-term technology cooperation relationships. This would enable a firm to establish a position of competitive advantage through customized customer value propositions based on reducing ecological impact.

Second, including economic importance adds another economic aspect to the socioeconomic research framework presented in Figure 1. Perception of economic importance associated with each ecological product attribute gauges its assigned cost importance in the current Cost-of-Ownership model.

Third, the determinant attributes presented in Table 24 can serve as the basis of quantifying expressed customer needs, thus providing an empirical way for a supplier to be market-oriented in terms of being responsive to expressed customer needs. Identification and targeting of specific market segments in such a manner is an integral part of value creation.

CUSTOMER BEHAVIORAL INTENTIONS

In this research, there are two user intentions that are presented as consequential market outcomes to suppliers, and they have different time horizons. The first is defined as a measure of ecological impact's importance when deciding which new products to include in upcoming trial evaluations, which is typically done in 2-5 year cycles. The second is a measure of how actively a user company will pursue cooperative partnerships with suppliers that purposefully develop products with lower ecological impacts, which has a 5-15 years time horizon.

The relevance of trial evaluation intentions is based on the industrial product adoption decision process illustrated in Figure 2, and cooperative agreements with customers are established methods of gaining competitive advantage.

For the Eco-Proactive segment, the belief construct was a significant predictor of trial testing intentions with its 1) ecological impact reduction, and 2) resource conservation factors having significant positive relationships with this intention. However belief was not a significant predictor of the cooperation intentions for this segment.

For the Cost-Centric segment, the belief construct was a significant predictor of technology cooperation intentions with only its ecological impact reduction factor having a significant positive relationship with this intention. However, belief was not a significant predictor of trial testing intentions for this segment.

The explanation of this difference in behavioral intentions of each segment has several theoretical and practical possibilities. Threat-rigidity hypothesis asserts that when an organization interprets a threat to be a lack of control over an external development (such as the Cost-Centric segment's interpretation of the ecological suitability trend as shown in Table 26), they tend to resort to cost control and emphasizing efficiency concerns (Sharma 2000; Chattopadhyay, Glick *et al.* 2001). This would explain their intention to form long-term partnerships with suppliers who are focused on ecological impact reduction since it improves their chances of control by knowledge sharing, buying time, and spreading the risk.

The threat-rigidity hypothesis can also be used to explain the intentions of the Eco-Proactive segment that views sustainability as an opportunity. This segment has a perception of a fair amount of control and is eager to invest in innovation that would facilitate anticipated gains afforded by the new trend. Such companies, with a sense of control, are more readily agreeable to trying new products that have a lower ecological impact.

Other explanations that reflect my opinion and industry specific opinions provided by three of the 13 panelist who were asked to help in interpreting the results (see Appendix D), include the possibility Eco-Proactive companies have a higher public visibility; which is also supported by the fact they have a higher percentage of captive companies as shown in Table 26. Also, Cost-Centric companies may be following as established industry practice of outsourcing non-core areas to their supplier base, which also increase's control by bringing in experts. Finally, the Eco-Proactive segment may not need to develop separate long-term relationships based on supplier ecological impact reduction, since they have already started such relationships by virtue of evaluating such suppliers in upcoming trial evaluations.

In summary, the belief factor associated with reducing the ecological impact of manufacturing operations was a significant predictor of both user intention variables; this factor also explained the highest variance in the belief construct.

The ecological concern attitude construct was a significant predictor of trial testing intentions with three of its four factors having significant positive relationships with this intention. However, the attitude construct was not a significant predictor of technology cooperation intentions.

The time horizon of the users intentions seems to matter. The more immediate trial testing intention had significant relationships with attitude and belief for the Eco-Proactive segment. Also, as shown in Table 40, users that exhibit this intention have a higher level of decision involvement and work at relatively larger companies, making them potentially lucrative marketing targets. In other words suppliers that reduce the ecological impact of their products can approach highly involved decision makers in large companies to including their products in upcoming trial tests.

The longer-term cooperation intention had a significant relationship only with belief and only for the Cost-Centric segment. However, as shown in Table 41, users that exhibit this intention have a relatively higher level of involvement. Therefore, a company that focuses on reducing its products' ecological impact can approach this segment with the longer-term proposition of working together on development of ecologically improved process technology that is a few generations into the future.

CONTRIBUTION TO MARKETING THEORY

This research adapted attitude theory in an industrial marketing context to address the rising ecological sustainability trend, which has both social and economic aspects. The trend has generated market needs that have not been sufficiently investigated in empirical marketing research (Banerjee, Iyer *et al.* 2003), and its socioeconomic nature has proven difficult address in business settings (Bansal 2002). Findings in this study are consistent with long held marketing assertions that developing customer-focused skills to fulfill market needs enables improved firm performance (Day 1994).

A research model was presented as a framework of identifying and satisfying expressed and latent market needs resulting from this trend, which is aligned with marketing's main contention that doing so in an effective and efficient manner is key to organizational success (Kotler 2003; Narver, Slater *et al.* 2004).

The research framework was applied and tested in the industrial marketing context of semiconductor manufacturing. In essence expanding the marketing concept's emphasis on satisfying industrial target market needs to also encompass socially oriented needs while suppliers maintain a disciplined market-based approach. The framework strikes the necessary balance between company profits, customer needs, and public interest (Kotler 2003).

Cognitive structure and attitude theory have been demonstrated as a suitable framework for examining socioeconomic dimensions such as ecological concern. This research adds to extant business marketing research by extending the application of cognitive structure based theory to measure beliefs about a specific category of product attributes (namely ecological attributes), quantify attitudes towards ecological impact in an industry, and determine how they are related to purchasing intentions of process equipment customers (Wildt and Bruno 1974); which ultimately influence supplier firms performance.

This amounts to applying a modified version of Rosenberg's two-factor linear attitude model (Rosenberg 1956) to business marketing that is specifically concerned with ecological (socioeconomic) variables in an industrial capital equipment context. As with any behavioral science theory, predictions are seldom definitive or unequivocal, yet such theories have practical use and are therefore worthy of serious consideration; it must be recognized that there is always uncertainty because human behavior can never be perfectly explained or predicted (Engel, Blackwell *et al.* 1986).

Cognitive structure of beliefs and attitudes has its roots in social psychology and is therefore able to accommodate the social aspects of the ecological sustainability business trend, which together with its ability to include customer behavior makes it a suitable business framework for exploring the socioeconomic aspects associated with ecological impact issues.

This adaptation is enabled by the universal nature of behavior theory's contention that inconsistencies in a person's cognitive structure regarding his beliefs, attitudes, and behavior is a psychologically uncomfortable state which results in pressures to eliminate or reduce the inconsistency. Such theories are used to understand how customers decide to purchase and how marketers can influence this decision process (Scott and Bennett 1971).

The research model presented in this study treats the improvement of a product's ecological attributes, based on customer preferences, as a potential source of competitive advantage. Responsiveness to external change and timely recognition of an opportunity and its pursuit in an effective and efficient manner is a recognized source of competitive advantage (Post and Altman 1994; Porter and Linde 1995; Prothero 1998; Grant 2002). Ecological impact reduction is now a relevant constraint in the semiconductor industry and many others. Suppliers that recognize this emerging opportunity can use this framework to assess the market-based benefits they can reap if they dedicate some of their research and development resources to pursue ecological impact reduction.

The relationships between belief, attitude, and behavioral intentions are considered a stable theoretical framework for investigating those relationships, with the main contention that measures of belief, attitude, and behavior are directly related (Fishbein and Ajzen 1975; Engel, Blackwell *et al.* 1986).

IMPLICATIONS TO MARKETING PRACTICE

As illustrated in Table 43, in the specific semiconductor equipment context of this study, there is a clear indication that marketing managers tasked with new product development programs can improve the adoption rates for new products, and increase their customer partnerships potential, by improving ecological product attributes. They would need to focus as much attention on attributes that minimize the ecological impact of customer operations as they do to attributes that maximize the efficiency of natural resource consumption.

Unlike natural resource related items, the impact reduction items are not expressed as important determinants in current economic models. However they form a factor that is a clear latent market need and is the only factor significantly positively related to both trial testing and cooperative intentions. Such attributes include modular subcomponents that can be recycled into other applications, upgradeable systems that have a maximized lifetime, efficient and recyclable packaging, product take-back service programs, and expanded disclosure of all materials of concern that help build trust.

Paying more attention to reducing operational impact does not imply reducing attention to the expressed needs of efficient energy, water, and materials requirements. They are distinct different market-orientation value drivers. The expressed efficient resource consumption need enables *responsive* market orientation and the latent impact reduction need enables proactive market orientation; where proactive orientation has been shown to produce better results in terms of new product success (Narver, Slater *et al.* 2004).

Another way of conceptualizing these results is that user decision time horizons matter. Addressing the research questions demonstrated that it is indeed useful for a company to focus on improving the ecological attributes of its products at two levels. It can approach customers in either market segment with a targeted message that is aligned with the segment's specific perceptions of current economic importance of ecological attributes. One message for the Eco-Proactive segment would emphasize the improved ecological attributes for consideration in upcoming trials tests, and the other message for the Cost-Centric segment would emphasize the supplier's role as an ecological problem solver (e.g. control enhancer) fit for a long-term technology development partnership.

Another consequential finding for equipment suppliers is related to relationships between behavioral intentions and demographic variables. They suggest that decision makers in larger companies are likely to consider the ecological impact of their product(s) when deciding on their inclusion in upcoming trials; minimizing that impact potentially provides them with a relative advantage. Also, in both trail evaluation and cooperation intentions, the level of decision involvement of the respondent was positively related to those intentions. Decision-makers want to address ecological issues, which is a positive outcome for supplier companies that offer impact reduction solutions.

The establishment of ecological belief and attitude measurement scales, segmentation of the market, and testing of the research hypotheses provided valuable insight to marketers looking to gain from the ecological sustainability trend. The framework presented in Figure 1 is a useful initial tool for understanding how the market outcomes relate to socioeconomic issues such as ecological sustainability; potential benefits supplier can reap if they dedicate some of their resources to addressing ecological impact.

Beyond the obvious need to only use reliable and valid scales that represent the social constructs, to avoid making the wrong inferences, marketers need to segment their customers based on the economic importance of same attributes that are used in the belief scale. Other benefits to such segmentation include improved positioning and targeting, adding an economic aspect to the research framework (the other aspect is purchasing intentions), and if segments are found then one could determine the attributes that differentiate between the two segments.

The process of establishing valid cognitive (belief and attitude) scales, and the discovery of their underlying structures provides marketers with valuable insight into the minds of their customers. For example, in this research, users had an attitude factor that is related to how a supplier company manages its environmental practices that was also a significant predictor of making trial evaluation decisions. Armed with such knowledge, a marketer can elaborate on her or his company's practices (of course assuming they are good practices) during customer interaction, this facilitates positive positioning of the supplier's image in the user's mind

In addition to insights from scale building, the belief scale has an economic tie with cost importances of its attributes. When such belief relationships are tested, in terms of their predictive ability of user behavior, they provide additional knowledge about specific segments. In this study, the Eco-Proactive segment had a positive relationship between their beliefs about attributes' ecological usefulness and was ready to include such attributes in trial testing decisions. The fact this segment also viewed the sustainable development trend as an opportunity, reflecting a perception of control, may be an indication of their eagerness to gain from addressing ecological impact issues; in other words they are ready to invest in such innovation (Chattopadhyay, Glick *et al.* 2001). A marketer could use such information to highlight a product's ecological attributes for such users and increase product adoption potential.

Cost-Centric customers had a positive relationship regarding their intentions to form cooperative relationships. The fact that this segment viewed sustainable development trend as a cost (or a threat), reflecting a perception of little control, may be an indication of a cost control strategy that would seek partners and buy time in order to improve control. They also may not consider ecological issues part of their core competence and hence they are not assigned high economic importance, or they may not have sufficient market visibility and not feel the need to be proactive. However such users clearly recognize that ecological issues are important issues and would form partnerships with companies that would take primary responsibility for addressing them. Again, a marketer could use such information to cultivate long-term relationships with such a segment.

In summary, ecological attributes of products are related to customer-value even if such relations vary for different segments; they form the empirical basis of quantifying latent and expressed customer needs. When combined with concern about the environment, ecological attributes help to predict customer decisions regarding new product adoption and long-term supplier cooperation.

LIMITATIONS OF THE STUDY

Linear attitude theory and regression analysis require the relationships between variables to be expressed using linear equations. Although that is a simplification of typically complex relationships, in the case of exploratory studies such as this it is often deemed acceptable (Hair, Babin *et al.* 2003).

Behavioral intentions may be affected by external situational factors that make them less correlated with belief and attitude (Sheth 1973). Several possibly relevant situational factors were not included in this exploratory study due to inability to determine *a priori* whether valid and reliable scales would be found or what their factor structures would look like. Most research in this area was of the organizational ethical decision-making ilk, hence this marketing study could not justifiably use established antecedent variables and had to develop scales and extract factors in an exploratory way.

To keep the complexity manageable, only individual factors were considered in this study and not situational ones. Some previous researchers have found that individual factors influenced intentions more than organizational or contextual ones (Morris, Rehbein *et al.* 1995). Others have demonstrated that some situational factors are relevant for inclusion, such as subjective norms about environmental behavior and slack resources (Flannery and May 2000; Sharma 2000). Now that the scales are established, future studies would benefit from considering three situational factors: subjective norms, availability of product alternatives, and available slack resources.

Another limitation of this study is the fact the proposed framework was tested in a very specific semiconductor industry context. Generalizing the model to other industries cannot be meaningfully achieved without similar industry specific tests to assess the approach's cross-industry robustness. This is particularly relevant in light of the industry-specific decision time horizons; there are no meaningful short-term decisions in the semiconductor market due to the process technology development (2-5 years) and research (5-15 years) cycles.

Although Chapter 4 addressed the adequacy of the 10% response in terms of similarity to other studies, it remains relatively low. This presents a risk of results generalization error, but that risk is mitigated by the large extent of industry representativeness. However, the small size of the sample limits the ability to use other data analytic tools for future research.
Semiconductor industry growth has several other relevant, and arguably more important, constraints on industry growth such as silicon wafer size, feature size reduction, defect detection, material availability, and others (Conroy 2006). This study does not address the effects of any other constraints and only investigates the ecological constraints and their details.

Finally, there are general bias limitations that may be present such as fatigue due to its length or the fact self-reported data may be subject to social desirability bias (Flannery and May 2000). However, an assurance of anonymity, such as the one afforded by this study, reduces such bias even when responses relate to sensitive issues (Sharma 2000).

FUTURE RESEARCH

To complement this research and address its limitations, possible future research might include using the same framework in another manufacturing industry setting (Flannery and May 2000). One industry that stands out is the construction industry due to its unique position of affecting a large swath of society and its established efforts of pursuing ecological sustainability. It is one of few industries with long established "green" standards such as the ubiquitous Leadership in Environment and Design (LEED) rating system.

Another study might apply the research framework presented in this dissertation to study all relevant semiconductor industry constraints at the abstract level (i.e. 450mm, low K, ecology, etc...) to get similar insights of all strategic issues as opposed to insight about the details of one of them. In other words, ecological considerations would be one abstract constraint along with other relevant technology and manufacturing constraints. A higher-level study that considers all constraints at their abstract level would be insightful and might shed light on the relative importance of each constraint.

Also, in future research, when soliciting perceptions of respondent views about the ecological sustainability trend in terms of being an opportunity or a threat, it would be beneficial to explicitly ask about views on the two different types of such opportunities and threats. In other words, ascertain whether the view is related to gain (or lack) of control or gain (or loss) of resources.

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APPENDIX A – SURVEY

Survey Title: Ecologically Sustainable Semiconductor Manufacturing

1) In your opinion, how will increased R&D focus on each of the following **FAB TOOL ATTRIBUTES** affect the attainment of ecologically sustainable growth of semiconductor manufacturing?

1 = greatly hinder
2 = hinder
3 = slightly hinder
4 = neutral effect
5 = slightly enable
6 = enable
7 = greatly enable

ID	Product Attribute	1	2	3	4	5	6	7
0	Energy requirements (B_ENERGY)							
1	Water usage (B_WATER)							
2	Overall mass of product (B_MASS)							
3	Number of hazardous materials (B_HAZMAT)							
4	Toxicity of materials needed (B_TOXCTY)							
5	Conversion efficiency (i.e. low emissions) (B_CONVRT)							
6	Recycled content in the physical product (B_RCYCLD)							
7	Recyclability of product components (B_RCYCLB)							
8	ITEM REMOVED FROM SURVEY							
9	Green house gas emissions (i.e. CO_2) (B_GRNHGS)							
10	Demanufacturability (B_DMNFCT)							
11	Remanufacturability (B_RMNFCT)							
12	Regulatory compliance cost (B_REGULT)							
13	Tool disposal cost at end of useful life (B_DSPCST)							
14	Generation of wastes during use (solid, liquid, or stack emissions) (B_WSTGEN)							
15	Segregation of waste streams (B_WSTSEG)							
16	Product packaging (reduced energy and materials, recyclability, and reuse) (B_PACKAG)							
17	Upgrade-ability (lifecycle extension) (B_UBGRAD)							
18	Full disclosure for materials of concern to customers (B_DSCLOS)							
19	Product take-back for free or at minimal charge (B_TAKBAK)							

APPENDIX A – SURVEY - Continued

2) How important is each of the following **FAB TOOL ATTRIBUTES** in your company's current decision-making method (i.e. Cost-Of-Ownership or Return-On-Investment)?

1 = very unimportant
2 = unimportant
3 = slightly unimportant
4 = neutral
5 = slightly important
6 = important
7 = very important

ID	Product Attribute	1	2	3	4	5	6	7
0	Energy requirements (I_ENERGY)							
1	Water usage (I_WATER)							
2	Overall mass of product (I_MASS)							
3	Number of hazardous materials (I_HAZMAT)							
4	Toxicity of materials needed (I_TOXCTY)							
5	Conversion efficiency (i.e. low emissions) (I_CONVRT)							
6	Recycled content in the physical product (I_RCYCLD)							
7	Recyclability of product components (I_RCYCLB)							
8	ITEM REMOVED FROM SURVEY							
9	Green house gas emissions (i.e. CO_2) (I_GRNHGS)							
10	Demanufacturability (I_DMNFCT)							
11	Remanufacturability (I_RMNFCT)							
12	Regulatory compliance cost (I_REGULT)							
13	Tool disposal cost at end of useful life (I_DSPCST)							
14	Generation of wastes during use (solid, liquid, or stack emissions) (I_WSTGEN)							
15	Segregation of waste streams (I_WSTSEG)							
16	Product packaging (reduced energy and materials, recyclability, and reuse) (I_PAKCAG)							
17	Upgrade-ability (lifecycle extension) (I_UBGRAD)							
18	Full disclosure for materials of concern to customers (I_DSCLOS)							
19	Product take-back for free or at minimal charge (I_TAKBAK)							

APPENDIX A – SURVEY - Continued

3) Please indicate your personal level of agreement with the each statement below.

1 = strongly disagree
2 = disagree
3 = slightly disagree
4 = neutral
5 = slightly agree
6 = agree
7 = strongly agree

ID	**Ecological Statement**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	Our industry's ecological problems are exaggerated (C_EXGGRT)							
1	I seek products that have minimal ecological impact (C_LOIMPC)							
2	Pollution caused by our industry does not create a societal problem (C_SOCIET)							
3	I urge colleagues and friends to consider ecological consequences of products they buy (C_CNSQNC)							
4	Pollution abatement is an effective ecological management tool (C_ABATE)							
5	Pollution prevention is an effective ecological management tool (C_PREVNT)							
6	My individual behavior will not make a difference in improving natural resource preservation (C_MYBEHV)							
7	Recycling is not an important concept and behavior (C_RECYLN)							
8	Not enough resources are allocated for environmental protection (C_PROTCT)							
9	Resource preservation should be a societal goal (C_PRESRV)							
10	Ecological benefits do not justify the expense of R&D (C_EXPENS)							
11	I am concerned over the well being of future generations (C_FUTGEN)							
12	Supplier environmental policies should be considered in purchasing decisions (C_POLCIS)							
13	ITEM REMOVED FROM SURVEY							
14	Suppliers should not have to disclose the entire ecological impact of their products, only what is required by law (C_DISCLS)							
15	It is possible to develop ecologically sound technology that is economically superior (C_ECNVLU)							
16	Firms should always put profitability before ecological considerations (C_PROFIT)							
17	Environmental protection should be a key element of any corporate culture (C_CULTUR)							
18	Ecologically superior products should not cost more (C_COSTSM)							
19	Ecological issues should not be a factor in business decision making (C_FACTOR)							
20	Manufacturers have a societal obligation for final disposal of their products (C_DISPOS)							

APPENDIX A – SURVEY - Continued

4) What is your personal level of knowledge concerning each of the ecological factors below?

1 = none existent
2 = much less than average
3 = less than average
4 = average
5 = more than average
6 = much more than average
7 = qualify as an expert

ID	Environmental concepts, issues, and terms	1	2	3	4	5	6	7
0	Greenhouse gasses (K_GRNHSG)							
1	Atmospheric acidification (i.e. acid rain) (K_ACIDRN)							
2	Industrial pollution of oceans, rivers, air, soil (including erosion), drinking water, and groundwater (K_H2OPOL)							
3	Climate change (i.e. global warming) (K_GLBWRM)							
4	Ozone atmospheric layer depletion over Antarctica (K_OZONE)							
5	Pesticide/insecticide caused pollution (K_CHMPOL)							
6	Volatile Organic Compounds (VOC) emissions (K_VOC)							
7	Radiation from storage of nuclear waste (K_NUCLAR)							
8	World population growth (K_POPGRO)							
9	Hazardous Waste Disposal and Landfill restrictions (K_WASTE)							
10	Effects of energy generation from fossil fuels (K_ENERGY)							
11	Resource conservation methods, tools, and costs (K_CONSRV)							
12	Full environmental cost accounting (K_ACOUNT)							
13	Environmental Management Systems (EMS) (K_EMS)							
14	Globalization of manufacturing and farming (K_GLOBLZ)							
15	International transport of hazardous wastes (K_HAZSHP)							

APPENDIX A – SURVEY - Continued

5) Please indicate your level of agreement with the following statement: (JOINT_RD)
For long-term process development (5-15 years) my company will seek out joint technology development partners that purposefully develop products with lower ecological impact.
1 = strongly disagree
2 = disagree
3 = slightly disagree
4 = neutral
5 = slightly agree
6 = agree
7 = strongly agree

6) For mid-term process development planned for the next 2-5 years, how important is ecological impact **to your company** when deciding which new products to include in trial testing? (IN_TRIAL)
1 = least important
2 = very unimportant
3 = slightly unimportant
4 = neutral
5 = slightly important
6 = very important
7 = most important

7) Please indicate your level of involvement in product selection(s) for trial evaluations: (INVLVMNT)
0 = not involved at all
1 = slightly involved (provide input)
2 = involved (recommend products)
3 = highly involved (specify products)
4 = I'm the ultimate decision maker

8) On a scale of 0 to 10 where 0 means "non existent" and 10 means "extensive", please indicate your perception of environmental regulations in your area. (REGULTNS)

9) On a scale of 0 to 10 where 0 means "no emphasis at all" and 10 means "heavy emphasis", please indicate the extent of your company's emphasis on adopting production practices that will minimize or forestall future regulations. (LEADSHIP)

10) In your manufacturing operation, how is know-how of ecological footprint reduction viewed? (ECO_KNOW)
0 = a critical function the company will retain and control (alone or with partners)
1 = a function that will be transferred or outsourced to an outside expert

11) Please indicate your level of agreement. (RDUCIMPC)
Reducing the ecological impact of our manufacturing is a strategic issue at our company.
1 = strongly disagree
2 = disagree
3 = slightly disagree
4 = neutral
5 = slightly agree
6 = agree

APPENDIX A – SURVEY - Continued

7 = strongly agree
12) What was your firm's total semiconductor sales revenue in 2004? please estimate in US dollars (SALES)
0 = > $10 billion
1 = $5 - $10 billion
2 = $1 - $5 billion
3 = $500 million - $1 billion
4 = <$500 million

13) How many employees work at your company? (SIZE)
0 = > 5000
1 = 1000 – 5000
2 = 100 – 1000
3 = < 100

14) Approximately, what % of your company's chip production is made for your company's use?
You may use any number between 0 and 100. (CAPTIVE)
For Example:
100%= Captive Integrated Device Manufacturer (IDM) such as TI or Intel, and
0% = A pure-play foundry that sells all produced chips to outside customers such as TSMC

15) Do you hold an executive position at your company? (EXECUTIVE)
0 = Yes 1 = No

16) What is your education level? (EDUCATN)
0 = high school
1 = some college
2 = college degree
3 = graduate degree
4 = PhD

17) How many years of experience do you have? (YEARS)

18) What value does your company place on being an environmental leader? (ECOVALUE)
0 = My company places high value on being an environmental leader
1 = My company places moderate value on being an environmental leader
2 = My company places low value on being an environmental leader
3 = Other – please specify_____

19) In general, how is the trend of ecologically sustainable development viewed at your company? (ELP_VIEW)
0 = Sustainability is viewed as an added cost
1 = Sustainability is viewed as a profit opportunity

20) Please provide your e-mail address for the $25 gift certificate (1st 300 respondents) and the results of the survey. An anonymous Internet based address is acceptable.

APPENDIX B – RESPONSE SOLICITATION LETTER

Supported by:
Semiconductor Equipment and Materials International (SEMI)
Semiconductor Industry Association (SIA)

Dear Semiconductor Industry Professional,

Ecologically sustainable development is a growing trend potentially affecting all economic sectors. The stated goal of the International Technology Roadmap for Semiconductors (ITRS 2003) is *continued expansion of manufacturing activities while reducing the impact on natural resources.*

I am a Ph.D. student in the School of Business Administration at Portland State University, and I need your help to complete my dissertation research survey. I am investigating the role of market forces as enablers of an economically and ecologically sustainable future. The study is concerned with attributes of equipment used at chip factories, and your perceptions and knowledge of various environmental issues.

Answering the survey questions should take less than 20 minutes. Please follow the link below to complete the survey. The first 300 respondents will receive a $25 Amazon.com gift certificate (or a website of your choice where Amazon is not available). You may also request a summary of survey results.

To complete the survey, please go to:
http://survey.oit.pdx.edu/ss/wsb.dll/dawood/EcoSemi.htm

All information you provide will be kept strictly confidential; only summaries of responses will be reported. Your survey responses cannot be linked to you in any way. The eligibility for the $25 gift certificate will be kept completely separate from your survey responses, and using an anonymous Internet based e-mail is acceptable.

Sincerely,
Dawood Abugharbieh

If you have concerns or questions about this study, please contact the Human Subjects Review Committee, Office of Research and Sponsored Projects, 111 Cramer Hall, Portland State University, (503) 725-4288. If you have questions about the study itself, contact Dawood Abugharbieh at (503) 407-3332.

APPENDIX B – RESPONSE SOLICITATION LETTER (JAPANESE)

後援:
Semiconductor Equipment and Materials International (SEMI)
Semiconductor Industry Association (SIA)

半導体産業界の専門家の皆様へ

環境的に持続可能な発展は、あらゆる経済分野に影響を与える可能性のある潮流であり、今後益々主流となっていきます。国際半導体技術ロードマップ(ITRS)は、自然環境への負担を軽減させながら、生産活動を永続的に拡大していくことを、その目標として掲げております。

私は、ポートランド州立大学の経営管理学部で博士号を取得中であり、学位論文のための研究調査に、皆様のお力をお借りできないかと考えております。私の研究は、市場要因が経済的かつ環境的に持続可能な将来を実現するものとしての役割についてであり、本調査は、半導体工場で使用される装置の属性と様々な環境問題に対して、皆様がどのようにお考えで、どのような知識をお持ちであるかに関するものです。

ご回答には、20分も掛かりません。下に示しますリンクをたどってください。ご回答いただいた方、先着300名の方に、Amazon.comの$25ギフト券(Amazon.comがカバーしていない地域では、希望される他のウェブサイトのギフト券)を差し上げます。また、ご希望の方には、本調査の要約を差し上げたいと存じます。

ご回答は、http://survey.oit.pdx.edu/ss/wsb.dll/dawood/EcoSemi.htmでお願いいたします。

いただいた情報は、極秘情報として扱います。すなわち、調査報告として使用されるのは、ご回答の要約のみです。皆様の回答から、皆様個人が特定されることはありません。また、$25のギフト券の資格と皆様の回答は、別個のものとして扱いますので、ウェブベースの匿名のメールアドレスで回答いただいても構いません。

以上、よろしくお願いいたします。
Dawood Abugharbieh
(ダウード・アブガービア)

本調査の実施について、ご不明な点、ご質問がございましたら、Human Subjects Review Committee, Office of Research and Sponsored Projects, 111 Cramer Hall, Portland State University, 電話:(503) 725-4288へご連絡ください。また、調査内容への質問は、私、Dawood Abugharbieh 電話:(503) 407-3332までご連絡いただきたく。

APPENDIX B – RESPONSE SOLICITATION LETTER (KOREAN)

<u>Supported by</u>:
Semiconductor Equipment and Materials International
Semiconductor Industry Association

반도체 산업에 종사하시는 전문가님께,

생태학적으로도 지속이 가능한 발전은, 모든 경제 분야들에 잠재적으로 영향을 미치고 있는 하나의 성장 추세가 되고 있습니다. 국제 반도체 기술 로드맵 (International Technology Roadmap for Semiconductor, ITRS)은 *천연 자원들에 대한 영향을 줄임을 통한 지속적인 제조활동의 확장*을 공인된 목표로 삼고 있습니다.

저는 Portland State University에서 비즈니스 행정을 전공하는 Ph.D. 학생이며, 저의 박사 학위 논문 설문 조사를 마치기 위해 귀하의 도움을 얻고자 합니다. 저는 경제적이며 생태학적으로도 지속 가능한 미래의 조력자로서의 시장 경제 집단 들의 역할에 대해 연구 중에 있습니다. 이 연구는 칩 제조 시설에 사용되는 반도체 장비들의 특성과 다양한 환경적인 문제들에 대한 귀하의 견해들 및 지식과도 관계가 있습니다.

설문에 응답하시기는 데는 대략 20분 정도의 시간이 소요될 것입니다. 설문에 끝마치기 위해서 아래의 링크를 참조하시기 바랍니다. 처음 설문에 응하신 300분께는 25달러 상당의 아마존 닷컴 (아마존을 이용 하실 수 없으실 경우 귀하의 선택에 근거한 다른 웹 사이트) 상품권이 지급될 것입니다. 또한 귀하께서는 본 설문 결과들의 요약을 요청 하실 수도 있습니다.

설문을 마치기 위해서 다음의 링크로 이동해주시기 바랍니다.
<u>http://survey.oit.pdx.edu/ss/wsb.dll/dawood/EcoSemi.htm</u>

귀하께서 제공하시는 모든 정보는 철저게 기밀이 유지될 것이며, 단지 설문 답변들의 요약본들 만이 보고될 것입니다. 귀하의 설문 답변은 어떠한 방법으로도 본 설문조사 이외의 다른 용도로 사용되지 않을 것입니다. [0]25달러 상당의 상품권 받으실 자격 요건과 귀하의 설문 답변들과는 아무런 연관이 없도록 유지될 것이며, 본 조사를 위해 익명의 인터넷에 기반을 둔 이메일 주소를 사용하실 수 있습니다.

Sincerely,
Dawood Abugharbieh

본 설문조사에 궁금한 점이 있으시면 다음 연락처로 문의 주시기 바랍니다. Human Subjects Review Committee, Office of Research and Sponsored Projects, 111 Cramer Hall, Portland State University, (503) 725-4288. 또한, 만약 설문내용에 문의 사항이 계시면 저에게 연락을 주십시오. Dawood Abugharbieh at (503) 407-3332.

APPENDIX B – RESPONSE SOLICITATION LETTER (CHINESE)

贊助機構:
Semiconductor Equipment and Materials International (SEMI)
Semiconductor Industry Association (SIA)

親愛的半導體產業專家,

生態環境維持發展有增長的趨向，並且影響著所有的經濟區域。國際技術路線圖(ITRS2003)的目標是爲 了讓半導體製造業活動持續的擴展 的同時
相對著減少對自然資源的衝擊。

我是一名商業管理學院博士研究生，在波特蘭州立大學 (PSU)。
我需要您的幫助來完成我的學術論文研究調查。我在調查市場力量的角色如何影響經濟和維持生態環境的未來。我的研究在於有關設備屬性被使用在晶圓片工廠, 和個人對於環境問題的領悟和知識。

回答問卷調查大約在20分鐘之內。請使用以下的網路連接去完成問卷調查。前300 個完成問卷調查者將得到禮券 - $25 Amazon.com (或是其他的禮券)。
並且您可以要求一份問卷調查總結。

前往問卷調查， 請到:
http://survey.oit.pdx.edu/ss/wsb.dll/dawood/EcoSemi.htm

所有您提供的資訊將被保密，只有總結報告將被發表。在任何情況下您所提供的資訊是不具名的。你的答案也不會影響 使用的$25 禮券。
可以使用匿名的電子郵件。

誠摯的感謝,
Dawood Abugharbieh

如果您對此研究调查有任何問題, 請 聯絡人類主題回顧研究委員會/ 主辦 單位. 111 Cramer Hall, 波特蘭州立大學 (PSU), 電話 - (503) 725-4288 。
如果您有關於研究的問題, 請與我聯繫 - Dawood Abugharbieh (503) 407-3332。

APPENDIX C – RESPONSE SOLICITATION (E-MAIL)

From: Lynne Johnson [mailto:ljohnson@sia-online.org]
Sent: Thursday, October 27, 2005 1:27 PM
Subject: Survey letter from Dawood Abugharbieh
To: Members

From: Chuck Fraust (cfraust@sia-online.org)
SIA and SEMI have agreed to support the research efforts of Dawood Abugharbieh, a doctoral student at Portland State University. As explained in the attachment, Mr. Abugharbieh is looking to study the importance of environmental factors such as ecological sustainability in deciding upon semiconductor manufacturing equipment. This survey is intended to be completed by ESH, process engineering and procurement personnel. The study is geared to identify individual attitudes and not to reflect company positions, per se. On behalf of Mr. Abugharbieh, I ask that you complete this survey yourself and make sure that it is sent to the proper EHS, process and procurement personnel for your company. All participants will have access to the survey results.

Thanks,

Chuck

....

Chuck Fraust, PhD, PE, CIH
Director, ESH
Semiconductor Industry Association
181 Metro Drive, Suite 450
San Jose, CA 95110
p: 408.573.6609 - f: 408.436.6646
www.sia-online.org

APPENDIX D – PANELISTS INTERPRETATION OF INTENTION RESULTS

Group #1 = Eco-Proactive segment
Group#2 = Cost-Centric segment

----- Original Message -----
From: from both panelists #7 and #10 in alphabetical order
My hunch is that group #1 tends to be focused on marketing to OEM customers or directly to consumers. Because of increased visibility, these companies tend to be scrutinized more by external stakeholders and see environmental performance as a key business imperative for continued success. I would further venture a guess that companies in Europe, US, and Japan would be more interested in environmental good citizenship and, thus, tools with less environmental impact. I think their attitude would be “I need to drive this internally as a company objective, including supplier environmental criteria.”

Conversely, I would guess group #2 may be more focused on a “low cost” model as their key to success – such as foundry companies in Korea, Taiwan, and elsewhere. If this is the case, these companies are sought out for cost, quality, and delivery objectives rather than environmental performance. They are less visible to external stakeholders and would be less motivated to improve environmental impacts. I think the attitude of this group would be: “If I need to do this I'll worry about it later and push my suppliers when needed, or let others in the industry lead the way and I'll ride their coat tails.”

This is all mainly speculation, of course, based on my observations.

----- Original Message -----
From: Panelist #4 in alphabetical order
I think your interpretation of the results is correct. The thought I'm having with regards to Group #1 and their long-term partnerships is that perhaps they believe that in the future, ALL companies will be moving towards sustainability and improved ecological attributes, and so they don't HAVE to develop relationships with the "early adopter" companies right now. Also, since they are using it as a factor in tool selection, I would argue that they are developing relationships with ecologically-minded companies, but that it is not the end-all/be-all (at this time) because the governments around the world are not yet forcing it to that level.