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GREEN SUPPLY CHAIN AND ECO-DESIGN IN ELECTRONIC INDUSTRY

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PURPOSE

GREEN Supply Chain Management (GSCM) is, today, gaining much importance in electronic industry due to pressure from the government and environmental consciousness among the customers, to gain competitive advantage. The purpose of this study is to investigate the determinants of adoption of eco-design. The relationship between the determinants and adoption of eco-design has been hypothesized. Based on the extant literature design for reduction, design for reuse, design for recycling, design for remanufacturing are identified as main determinant and studied.

Design/Methodology/Approach: *Electronic Companies of Noida were sampled for the empirical study. A survey was carried out with a sample of 150 companies in electronics industry.The survey instrument was shown to be both reliable and valid. The empirical model was tested using regression analysis, to verify the hypothetical relationships of the study.*

Findings: *The results indicate that Eco design is positively related with three factors including environmental, market, and company pressure and it is positively related with organisational performance.*

Research Limitations/Implications: *The accuracy of the analysis is dependent upon the accuracy of the data reported by selected companies.*

Practical Implications: *The result of this study would enable understanding of the academic community as well as the practitioners who are trying to incorporate green supply chain or environmentally sustainable / responsible supply chains.*

Originality/Value: *This study is perhaps the first to systematically determine the determinant of eco-design in the electronic sector in Noida. It offers a beneficial source of information to electronic organisations, which are in the process of adopting best practices of GSCM.*

Key Words: Green supply chain, Environmental performance, and Eco-Design.

Introduction

As the world has already reached "post-Kyoto" environment where climate change will be causing people, organizations, and institutions to alter their life styles with the focus of sustainability issues which will remain in the long-term psyche of managers, engineers, politicians, and community leaders. The concern over sustainability has been increasing.With increase in environmental concerns during the past decade, a decision is being framed that all the environmental pollution issues accompanying

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industrial development should be addressed jointly with supply chain management, thereby contributing to green supply chain management (GSCM) (Sheu *et al.,* 2005). Since the Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) and Eco design for Energy using Products (EuP) directives were passed by the European Union (EU), GSCM has been adopted as a proactive strategy by various leading electronic industry companies, including Dell, HP, IBM, Motorola, Sony, Panasonic, NEC, Fujitsu, and Toshiba (Zhu and Sarkis, 2006).Thus, GSCM practice can be denoted as the major strategy capable of complying with the needs of legislations and maintaining the competitive gain. Having a glimpse over more systematic and integrated strategy, GSCM has emerged as a vital new innovation that helps organizations to develop "win-win" strategies that will lead them to achieve profit and market share objectives by lowering the risk of environment and there effects by raising the ecological efficiency .Green supply Chain Management (GSCM) is an advent to improve conduct of the process and various products according to the requisites of environmental regulations (Hsu & Hu, 2008). GSCM has appeared in the last few years and covers all phases of product's life cycle from design, production and distribution phases to the end use of products by its users as well as its disposal at the termination of product's life cycle (Borade & Bansod, 2007). GSCM is fusing environmental thinking (Gilbert, 2000) into Supply Chain Management (SCM). Even in India understanding level of customers of Green practices opted by organizations has also seen as increment. So organizations need to focus on the utilization of energy and resources for making environmentally sound supply chain.

The Green supply chain management has directly influenced environmental management onto the supply chain level. Thus the essential issue is the eco-oriented design of inter-organizational processes. The green supply chain management concept enlarges the hitherto inner-oriented horizon of ecological efforts by relationships of multiple companies because isolated solutions can only lead to small improvements. Accordingly, suppliers, manufacturers, customers, and disposal companies must be combined in enforcing green supply chain management. Accordingly, Hoek (1999) calls for assessment of the 'ecological footprint' of a company so that it may lower the environmental damage of business. Hick (2000) even claims that the concept of green businesses enforces the re-assessment of the essential intent of a company's existence.

The "green" element being added to supply chain management associates the impact of supply chain management on the natural environment. The environment conscious people have motivated it and thus it can also stem from a competitive motive within organizations (Hervani, Helms, and Sarkis 2005).

This paper address the issue of Eco-design as promising area of study in electronics companies of Noida (U.P.) region that have the potential to provide significant benefits to the firm and the society. The study tries to identify key factors which can affect the adoption of eco-design and its impact on organisational performance. This paper has used factor analysis and regression analysis to find the factors impacting the enterprise eco-design. The next section presents a review of the literature that focuses on the green practices including eco-design. This literature leads to the study's hypotheses, and then it is followed by data analysis. Lastly, the paper portrays the significance of the study and its contributions.

Eco-design Concepts

Eco-design is the logical consideration of the design performances with respect to environmental, health and safety objectives over the full product and process life cycle (Fiskel and Wapman 1994). It is actually possible to focus on a specific stage of the life cycle such that the environmental impact is minimized at that stage as well as emphasizing the entire life of the product.

There are various other names of eco-design such as green design, design for environment, sustainable design, environmentally conscious design, and life cycle design. It takes place early in the product's design or upgrade phase, to ensure that the environmental consequences of the product's life cycle are understood before manufacturing decisions are committed.

While designing sustainable products, other constraints including economics, technological possibilities, and limitations along with the benefits to the customer have to be considered (Luttropp 1999). The environmental demand, economic reality, and technical possibilities must be optimized when designing for a sustainable society (Luttropp and Züst 1998). So, eco-design is one of the green supply chain initiatives because it combines environmental aspects into product design process, taking into consideration entire flow of the product in its supply chain. This consideration is very important because the majority of environmental impacts arising from production, consumption, and disposal of the product are direct consequences of decisions made at the design stage (Handfield, Melnyk, Calantone, & Curkovic, 2001). Different stages of product's life cycle are analysed by researchers and they developed methodologies to improve the design of the product from an environmental perspective. As a result, eco-design was broken down into many stages including product's manufacturing, use and end-of-life (EOL). According to Horvath (Horvath and Hendrickson, 1995), to achieve eco-design, three main goals must be pursued:

- minimize the use of non-renewable resources
- effectively manage renewable resources
- minimize toxic releases to the environment.

Aims may be transformed into specific eco-design strategies. For example, to reduce the energy used and minimization of the wastes during the production design objectives may include design for energy conservation. In order to lessen the energy consumption during the use phase, strategies like Design for Energy Savings were developed. During the last decade the EOL phase has received an increased attention. The particular eco-design actions or activities vary between companies and products. The most popular of the strategies are Design for reduction/elimination, Design for Reuse, Design for Recyclability (Recovery), Design for Remanufacturing, and Design for resource efficiency.

1. Design for reduction or elimination of environmentally-hazardous materials, such as, lead, mercury, chromium and cadmium (Zsidisin and Siferd, 2001).
2. Design for reuse, is a design that facilitates reuse of a product or part of it with no or minimal treatment of the used product (Sarkis, 1998).
3. Design for recycling, is a design that facilitates disassembly of the waste product, separation of parts according to material, and reprocessing of the material (Lin, Jones, and Hsieh, 2001).
4. Design for remanufacturing, is a design that facilitates repair, rework, and refurbishment activities aiming at returning the product to the new or better than new condition (Beamon, 1999).
5. Design for resource efficiency, including reduction of materials and energy consumption of a product during use, in addition to promoting the use of renewable resources and energy.

The function of eco-design is to help design so that the environmental impact is reduced during the whole life cycle. The following qualitative analysis positions the eco-design in the context of globalized markets.

Materials

One of the central issues addressed by eco-design for the energy using products is the reduction in material use and it is the priority for products not using energy. Whether they are manufactured near to the customer or not doesn't make any difference in terms of amount of material needed. The difference comes from the ecological burden created by the extraction of raw materials. Globalization may change the raw material extraction to the manufacturing region (China, Mexico, India, etc.), which in most of the cases occurs in countries with older and more energy intensive technologies, where the legislation is less restrictive in terms of discharges, waste, human health, and safety.

Manufacturing
Eco-design affects the efficiency of the manufacturing process as well. From the point of view of eco-design, decisions on the selection of the manufacturing processes are trade-offs between economic and environmental criteria. Outsourcing permits less control over the manufacturing processes, and there may be a great discrepancy between the design intention (and thus the estimated environmental performance of the processes) and reality at the supplier (different manufacturing processes, waste management, etc.). In most of the cases this is injurious to environment and the eco-design may become a simple game of chance.

Packaging
Packaging has numerous roles: protect, handle, information on the product, and promotion of the brand. Shipping to and from abroad dramatically raises the number of manipulations, and thus the risk of failure due to shock exposure. From a design point of view it indicates that either the product should be less sensitive to shocks or the package should be designed to better protect it. Similarly, a double packaging may take place (bulk packaging and later individual at the distribution centers). Either way, it acts against the eco-design ethics to decrease the quantity of packaging.

Transport and Distribution
The vast increase in the distance a product travels before attainment of the customer, as opposed to locally produced goods, is probably the main adverse effect on environment. Although these are the consequences of prevailing economic decisions, optimizing the weight and/or the volume of the product and its package plays an important role in reducing both environmental impact and cost due to transportation.

Use
From an ecological point of view the use phase pays the most to the environmental influence for two broad categories: energy using products and products making use of consumable. Eco-design targets at decreasing the energy consumption (useful and standby where applicable) and the amount of consumables during the life time (e.g. paper bags for a vacuum cleaner, paper filters for a coffee machine). There is a positive correlation between the energy consumption, cost of ownership, and negative impact on environment. This state of the facts induced no incentive for producers to focalize efforts towards this direction. The consciousness of the consumers on the environmental issues has put pressure on companies to reduce the energy consumption, combined with eco-labelling and smart marketing strategies. Also, the environmental load is different for the same quantity of energy consumed in different regions, depending on the its production origin

End-of-life
End-of-life has been by far the attention of the eco-design, although this stage counts in average for less than 10% of the life cycle environmental load (as opposed to use 50% or materials 25%).Generally, eco-designed products are aimed considering the following end-of-life aspects:

- longer useful life (reusability)
- remanufacturability
- great recyclability
- potential for energy recovery.

This direction is not always desirable, like it is the case of a product embedding new technologies which allow reducing the life cycle impact (e.g., it would be worse extending the lifetime of an old generation fridge with a high energy consumption than recycling and replacing it with a new low energy consumption and CFC free – this may be true from an economic point of view too).

Recyclability is in most of the cases the utmost needed characteristic of the products reaching the final disposal phase (end of last life). Beginning with the 1970s recycling was performed for business, due to the large proportions of metals and precious metals. In the 1990s the owner used to pay the recycler (recycling for environment), while since 2000 the producers have paid recyclers to treat the EOL products, which meanwhile became more recycling friendly.

Technological, economic, geographical, and legislative uncertainties make the task of optimizing for EOL very challenging. Eco-design encouraged optimizing products for disassembly, mainly due to the wide spread idea that disassembly plays an important role in there cycling strategy, academic research finding a reach ground for subjects, often pushed to the highest degree of worthlessness and unrealism. Reality, in the developed countries, shows that mechanical treatment (shredding, sorting) and smelting processes are dominating, given the high labour rates of manual disassembly and heterogeneity of the income flow of products to be recycled.

Under these situations, eco-design can help in planning products that are stronger with respect to the EOL treatment. In other words, regardless of the EOL treatments employed and geographical location, a high recyclability rate, economic efficiency, and minimal impact on environment is the ultimate goal. Advances in the development of separation and sorting technologies favour the "design for non-disassembly" approach (Ram et al. 1998) combined with the design for easy removal of the hazardous parts and substances before mechanical treatments.

Electronics Industry

India is one of the fastest developing markets of electronics in the world. Electronics Industry reported at USD 1.75 Trillion is the leading and fastest growing manufacturing industry in the world. It is expected to reach USD 2.4 Trillion by 2020. The demand in the Indian market was USD 45 Billion in 2008-09 and is expected to reach USD 400 Billion by 2020. Today electronics manufacturers face some hurdles such as instability in manufacturing costs, skill labour need, technology change, exchange rate, impacts of high competitiveness, environmental legislation, and directives as well.

Reverse views of electronics supply chain also challenge with incremental wastes of end-of-life (EOL) products such as computers and home appliances. In addition low quality of electronics products is imported with higher rate which has increased waste from short lifetime. There are various obstacles for waste management like small number of effective recycling and disposition system, incomplete collection infrastructure, lack in incentives to separate recycled or hazardous substances, ineffective law enforcement, and technology limitation in community level. In order to overcome these problems it is imperative to determine short and long-term strategies for electronics manufacturing and electronics waste management and forced to implement seriously for better effective forward supply chains and reverse logistics.

Literature Review

It is important to integrate environmental management practices into the whole supply chain management in order to achieve a greener supply chain and maintain competitive advantage and also increase business profit and market share objectives. Various definition of GSCM exists in the literature. Accordingly, Zhu and Sarkis defines GSCM as has ranged from green purchasing to integrated supply chains starting from supplier, to manufacturer, to customer and reverse logistics, which is "closing the loop". According to Srivastava, GSCM can be defined as "integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life". Green supply-chain management (GSCM) is gaining increasing interest among researchers and practitioners of operations and supply chain management. The past literature also shows that most researchers have studied the GSCM adoption and implementation on developed countries such as Japan, Germany, Portuguese, UK, and Taiwan and so on.

Lippmann (1999) proposed various critical elements for the successful implementation of supply chain environmental management. Those components include the production of written GSCM policies, supplier meetings, training, collaborative R&D, top-level leadership, cross-functional integration, effective communication within companies and with suppliers, effective processes for targeting, evaluating, selecting and working with suppliers and restructuring relationships with suppliers and customers.

US-AEP (1999) improved understanding of industry approaches to supply chain environmental management (SCEM) by focusing on seven major electronics firms. Some of the common SCEM tools employed by these firms are summarized as follows:

- Prequalification of suppliers
- Environmental requirements during the purchasing phase
- Supply base environmental performance management Building environmental considerations into product design
- Cooperating with suppliers to deal with end-of-pipe consumer environmental issues
- Reverse logistics
- Influencing legislation to facilitate better SCEM policies
- Working with industry peers to standardize requirements (for suppliers and purchasing items)
- Informing suppliers of corporate environmental concerns
- Promoting the exchange of information and ideas.

Green supply chain management (GSCM) involves traditional supply chain management practices integrating environmental criteria or concerns into organizational purchasing decision and long term relationships with suppliers (Gilbert, 2000).

Bowen et al. (2001) conducted an exploratory analysis of implementing patterns and inductively derived three main types of green supply. The first type, i.e., greening the supply process, represents adaptations to supplier management activities, including collaboration with suppliers to eliminate packaging and recycling initiatives. The second type, i.e., product-based green supply, attempts to manage the by-products of supplied inputs such as packing. The third type, i.e., advanced green supply, includes more proactive approaches such as the use of environmental criteria in risk-sharing, evaluation of buyer performance, and joint clean technology programs with suppliers.

Rao (2002) argues that GSCM practices should include working collaboratively with suppliers on green product designs, holding awareness seminars, helping suppliers establish their own environmental programs and so on. To green the supply chain, from the perspective of practitioners, companies have to integrate the ideas of green purchasing total quality management in terms of employee empowerment, customer focus, continuous improvement, zero waste, life cycle analysis, and environmental marketing. Green purchasing comprises a number of environment-based initiatives, including a supplier environmental questionnaire, supplier environmental audit and assessments, environmental criteria for designating approved suppliers, requiring suppliers to undertake independent environmental certification, jointly developing cleaner technology/ processes with suppliers, engaging suppliers in eco design and product/ process innovation.

Rao (2002) pointed out that the green supply chain management activities include the organization itself the green activities and parts suppliers. Zhu and Sarkis (2004) is the study of China's manufacturing sector mentioned in the green supply chain management, including internal environment management, external Green Supply Chain Management, investment and eco-design. Green Supply Chain Management into the external environment management, and internal environmental management (Rao, 2002).

Zhu *et al.* (2005) described a number of GSCM practices implemented by Chinese enterprises to improve their performance. Internal environmental management is a key to improving enterprise performance in terms of senior manager commitment and cross-functional cooperation. Commitment of senior managers is extremely conducive to the implementation and adoption stages for GSCM, because without such upper management commitment most programs are bound to fail. All GSCM practices are integrative and require cross-functional cooperation rather than simply being oriented to a single function or department. They suggested that green purchasing and eco-design are two emerging approaches and companies should focus on the inbound or early portions of the product supply chain. To attain improved environmental performance, large customers have exerted pressure on their suppliers, resulting in greater motivation for suppliers to cooperate with customers for environmental goals.

The implementation of green supply chain management practices and the organization's environmental performance and economic performance have the positive relations (Zhu and Sarkis, 2004). Green supply chain management practices are rather wide range, from internal and external. Green supply chain management practices include internal environmental management, external green supply chain management, investment and restore the ecological design or environment practical design (Zhu and Sarkis, 2004)

Chung-Hsiao (2008) studied the Green supply chain management in the electronic industry in which they mentioned that there are various approaches for implementing green supply chain management practices that have been proposed and recognized in previous literatures according to the author, but there is yet no investigation that identified the reliability and validity of such approaches particularly in electronic industry.

GSCM is the summing up of green purchasing, green manufacturing, green packing, green distribution, and marketing. GSCM is to eliminate or minimize waste in the form of energy, emission, hazardous, chemical and solid waste (Olugu, Wong, and Shaharoun, 2010).

Meanwhile, Table 1 also presents the previous studies of GSCM among manufacturing industry. These researchers had focused to specific industry in order to get depth understanding of GSCM practices without comparing with different industries.

Research Model

This study identified factors of eco_design on the basis of previous literature review. Figure 1 shows the conceptual framework of this study.

The drives or pressures upon companies to implement GSCM include regulations, marketing, suppliers, competitors and internal factors (Zhu and Sarkis, 2006). The pressure of environmental protection does not come solely from the demands of regulations; consumers and clients also exert pressure on companies (Hall, 2000). Standards, regulations and competition have together prompted organizations to become more aware of any consequences for the environment (Sarkis, 1998). On the other hand, the regulatory, organizational, community and media stakeholders have prompted companies to conduct environmental management (Henriques and Sadorsky, 1996). Environmental regulations and external stakeholders are considered the major factors affecting GSCM practices according to Zhu and Sarkis (2006), Hall (2000), Sarkis (1998) and other experts.

Environmental Policy

Environmental regulation plays a critical role in the process of implementing the environmental management within the companies and it act, as one of the main drivers for product-based eco-innovation activities appears to be companies' efforts to comply with existing and future legal and normative requirements. Environmental policy is a key factor influencing innovation activities. At the same time, however, companies tend to anticipate that such innovative activities – if undertaken

Table 1: Previous Studies of GSCM

Year	Title/Author	Variables	Country/ Industry
2011	The Implementation of Green Supply Chain Management Practices in Electronics Industry Ninlawan *et al.*	- GSCM Practices - GSCM Performance - GSCM Pressure (Market, Regulatory, Competition)	Thailand; Electronic (Computer Part) sector
2011	An Analysis of the Drivers Affecting the Implementation of Green Supply Chain Management Diabat and Govindan	Drivers of GSCM (11 types of Drivers involved in this study, collected through several previous studies)	India; Aluminium sector
2011	Research on the Performance Measurement of Green Supply Chain Management in ChinaYan Li	Eco-design level; Green purchasing level; Green manufacturing capacity; Green marketing and consumption; Recycling products processing ability; Level of information technology; Comprehensive level	China
2011	The impact of green supply chain practices on company performance: the case of 3PLs Cagno *et al.*	Green Supply Chain Practices (GSCP) - 3PLs performance	Italy
2010	A Taxonomy of Green Supply Chain Management Capability among Electronics-related Manufacturing Firms in Taiwan. Shang *et al.*	• Green Manufacturing and Packaging • Environmental Participation • Green Marketing • Green Suppliers • Green Stock • Green Eco-design	Taiwan; Electronic Industry
2010	Green Supply Chain Management in Leading Manufacturers – Case Studies in Japanese Large Companies Zhu *et al.*	GSCM Drivers (Normative Pressure, Coercive Pressure, Mimetic Pressure) • GSCM Practices (Internal & external dimensions) • GSCM Performance (Economic, Financial, Operational)	Japan
2009	An Empirical Study of Green Supply Chain Management Practices Amongst UK Manufacturers Holt, D. and Ghobadian, A.	External drivers (Legislation, Competitive, Supply Chain, Societal) • Internal drivers	UK
2008	Green Supply Chain Management in the Electronic Industry Hsu, C.W. and Hu, A.H.	Approach for implementing GSCM: Supplier management, product recycling, organizational involvement, life cycle management	Taiwan; Electronic Industry
2008	The Driver of Green Innovation and Green Image – Green Core Competence Yu-Shan Chen	Green core competence • Green innovation: Green product innovation performance, Green process innovation performance, and Green images information	Taiwan; Electronics industry
2007	Greening the Automotive Supply Chain: A relationship perspective Simpson *et al.*	• Customer environmental performance requirements • Supplier environmental commitment	Australia; Automotive industry

Figure 1: Conceptual Framework

Factors affecting adoption of Eco-design **Organizational performance**

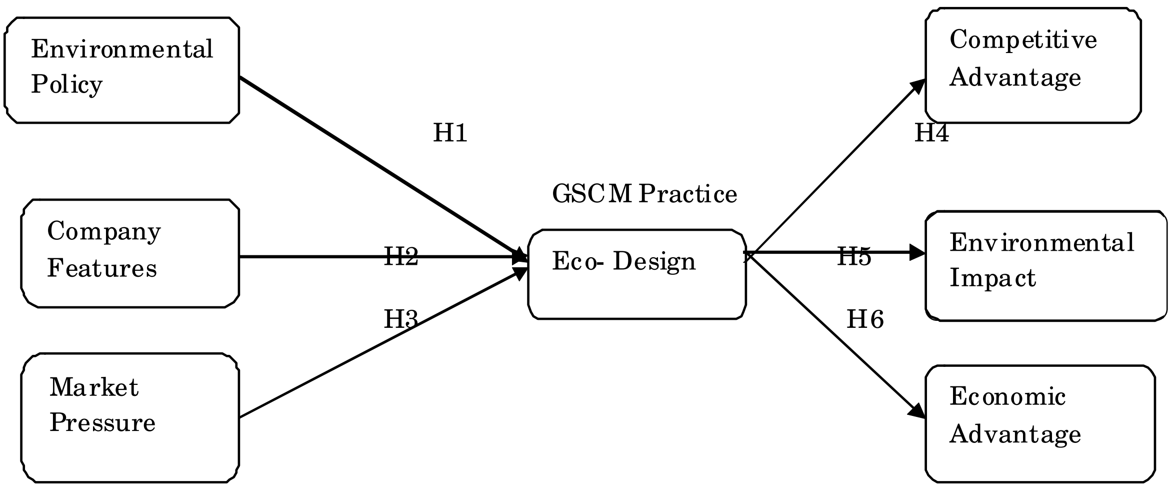

Figure 1: Research framework for investigation of relationships between factors affecting adoption of Eco-Design and its impact on Organisation Performance.

at an early enough stage – will generate lower costs in the medium and long term. Further catalysts for product-specific environmental innovations are:

– Early identification and analysis of potential improvements regarding the disposal, treatment, and use of recyclable waste including early and appropriate protective measures.

– Securing long-term markets by preparing for future market and customer needs.

This suggests that, in the long term, regulatory instruments generate an innovation dynamic which impels companies to engage in innovation activities which by far surpass the legal and normative requirements. Comparative studies on the innovation incentive effects of individual environmental instruments reveal that economic instruments (taxes and permissions) are preferable to regulatory instruments as they represent a permanent inducement to companies to look for broader, cost-efficient means of easing the environmental burden. On the other hand, regulatory instruments which are anticipated to come into effect in the future also have an incentive effect by initially alerting firms to the existence of specific problems. Global products face a greater challenge due to the heterogenic environmental legislation worldwide. Moreover, life cycle compliance with regulations is adding complexity to the product design, requiring the shift from the *cradle to grave* approach to the *cradle to cradle* (legislation will play a major role in making this a requirement and not an option). Some of the EU regulations that producers have to comply with when designing and producing new products or retiring existing ones are End of Life of Vehicles (ELV 2000), Waste of Electrical and Electronic Equipment (WEEE 2003), Restriction Of The Use Of Certain Hazardous Substances In Electrical And Electronic Equipment (RoHS 2003), Energy Using Products (EuP 2005). Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH 2007). Environmental regulations is considered to include domestic environmental regulations, government environmental policies and international environmental agreements according to Zhu and Sarkis (2006) and other experts.

Domestic Environmental Regulations

Domestic environmental regulations prompt companies to adopt relevant strategies and practices to enhance their environmental performance. Domestic regulations and corporations' environmental missions are the two main sources of pressure (Zhu and Sakis,2006). Furthermore, the major drive for corporation environmental awareness is increasing the role of Government regulations (Handfield, *et al.*, 1997).

Government Environmental Policy

The public's increasing environmental conscience, the statutory requirements due to government policiesand regulations, and pressure from organized groups are traditionally considered to be the factors that sway companies towards adopting a green manufacturing or environmental management system policy (Hui, *et al.*, 2001). Environmental policy targeted directly at emissions will still typically provide the most important single element of a cost-effective environmental policy strategy (Jaffe *et al.*, 2005).

International Environmental Agreements

Although domestic environmental regulations seem to have a greater and more immediate effect on eco-design than the type of economic policy incentive currently associated with WEEE (Gottberg, *et al.*, 2006), many companies and the government are also being influenced by international environmental agreements, such as the Kyoto agreement, the Climate Change Treaty and the Montreal Protocol (EIC, 2005).The EU WEEE directive attempts to tackle the growing quantity of WEEE by making producers responsible for the costs of the collection and recycling of their products at the end of usable life (Gottberg, *et al.*, 2006). Based on the above arguments, a hypothesis can be made as follows.

Hypothesis 1: There is positive relationship between Environmental regulations and adoption of Eco-design.

Company Specific Features

Finally, company size also appears to be an important factor influencing a company's product related innovation effort. While big firms tend to engage in the mass production of environment friendly products, smaller firms are more likely to attempt to penetrate small market niches by producing specialised eco-products. A further impetus to eco-innovation is the personal involvement and commitment of individual employees – particularly those in the company's R&D department – who often ensure that project innovations are implemented despite the uncertainty and risk attached to such activities. Other important company-specific factors are corporate culture and attitudes towards environment- related topics. The study revealed that, on the whole, all the firms surveyed emphasise the importance of the company's endeavours in the field of environmental protection. Companies are either certified to the EMAS scheme or the ISO 14001 standard. Environmental protection is now also an integral element of the guidelines used by all the companies surveyed, which suggests that environmental protection objectives – alongside and at the same level as corporate business and social objectives – are pursued throughout entire companies.

The importance of these objectives is also highlighted by:

– High production and manufacturing standards

– High innovation efforts in ecological areas

– Strong commitment to social responsibility

These companies explain their commitment to environmental protection in terms of the direct business advantages which accrue from reductions in energy costs and waste, attracting attention, conveying a positive corporate image to the media and social institutions as well as motivating employees. Last but not least, the earlier a company begins to perform environmental related activities, such as energy-saving-programs, the more expertise it is able to acquire in this field. As a result, these companies are able to fall back on a relatively broad base of knowledge which can lead to the generation of further environmentally-friendly eco-innovations.

Hypothesis 2: Company's features have a positive relationship with adoption of Eco-design.

Market Pressure

The high potential inherent in environmentally-conscious product use means that customer's utilisation behaviour is just as important as their spending behaviour. These behaviour patterns not only influence the utilisation-related environmental impact of products, they also determine market demand and, as a result, the innovation activities of companies. The intensity of market factors appears to vary according to sector and consumer group, however. In the electrical industry, in particular, original equipment manufacturers (OEM) and major customers demand that ecological criteria are met. The typical end-customer of electronics products, by contrast, is more concerned with the balance of technical features and price. Consumers of personal and health goods, such as foodstuffs, textiles or home- improvement materials, on the other hand, demand that environmental aspects are taken into account by manufacturers. So customer demands have now become the most important type of external pressure (Doonan, *et al.*, 2005). To obtain more sustainable solutions, the environmental properties of products and services must meet customer requirements (Zhu and Sarkis, 2006). In the U.S.A., an estimated 75% of consumers claim that their purchasing decisions are influenced by a company's environmental reputation, and 80% would be willing to pay more for environmentally friendly goods (Lamming and Hampson, 1996). Consequently, the influence of the natural environment organizational decisions not only affects the organization that makes the decision, but also its customers and suppliers (Sarkis, 2003). Suppliers contribute to the overall performance of a supply chain, and poor supplier performance affects the performance of the whole chain (Sarkar and Mohapatra, 2006). Supplier – manufacturer relationships are considered important in developing a sustainable competitive advantage for the manufacturer (Sheth and Sharma, 1997; Cannon and Homburg, 2001). Screening of suppliers for environmental performance has now become a key deciding factor in many organizations (Clark, 1999).

Hypothesis 3: Market pressure has a positive relationship with adoption of Eco design.

Organizational Performance

Performance is a measure for assessing the degree of a corporation's objective attainment (Daft, 1995). Corporations adopting GSCM practices may generate environmental and business performances (Walton, *et al.*, 1998; Zhu and Cote, 2004). A green supply chain, for example, can improve environmental performance (reducing waste and emissions as well as increasing environmental commitment) and competitiveness (improving product quality, increasing efficiency, enhancing productivity and cutting cost), thereby further affecting economic performance (new marketing opportunities and increasing product price, profit margin, market share, and sale volume; Purba, 2002). According to Walton, *et al.* (1998), Zhu and Cote (2004) and Purba (2002), as well as other experts, organizational performance is considered to include environmental and financial performance.

Competitive Advantage

When one examines the impacts of environmental initiatives at the firm level, the arguments and evidence point to two conflicting views. At one end of the spectrum, Walley and Whitehead (1994) have argued that the higher costs of environmental management initiatives mostly yield a negative financial return to shareholders. At the other, Klassen and McLaughlin (1996) demonstrate that strong environmental performance positively affects firms' financial performance and market evaluation and that the reverse is equally true. Doubts can, therefore, be raised that financial markets encourage "short-terms, profit only mentality that ignores much environmental reality".

Anecdotal evidence from leading firms illustrates that the business reasons for greening go beyond ethical issues to gain *competitive advantages*. For instance, the well-known 3M program, “Pollution Prevention Pay”, demonstrates the potential of cutting costs with environmental initiatives. DuPont also builds profit from waste and pollution reductions. But, more than cutting costs, environmental initiatives are linked to lean production practices for Honda of American Manufacturing. Environmentally responsive firms also find new ways to better satisfy market demands and increase their sales. Consider Wall Mart with its green labelling program which generated a 25 percent yearly increase in sales. Are these competitive advantages sustainable? Firms that move ahead are better positioned in the future to meet tighter standards and create market barriers to entry. Corporate environmental initiatives trigger *innovation* with the introduction of more environmental friendly products or processes and often require the adoption of state-of-the-art environmental technologies. Although environmental leadership is considered as a technology driver, it also promotes managerial innovations. Furthermore, environmental concerns cannot be properly addressed by pursuing separate isolated activities but must be tackled in a comprehensive and systemic manner, requiring inter functional integration within the firm but also upstream and downstream integration with suppliers/subcontractors and customers. Integrating environmental issues into corporate strategy is a catalyst for radical innovation for firms and for all actors along the supply chain. A fourth proposition is, therefore, outlined below:

Hypothesis 4: Eco-design has a positive relationship with competitive advantage.

Environmental Performance

Environmental performance is defined as the environmental impact that the corporation’s activity has on the natural milieu (Sharma and Vredenburg, 1998). Environmental performance indicators consists of OPI (operative performance indicators) and MPI (management performance indicators): OPI are related mainly to materials’ consumption, energy management, waste and emission production, and evaluation of real environmental aspects of organizations, whereas MPI mainly concerns the administration’s efforts, measures, and contribution to the overall organization’s environmental management (Papadopoulos and Giama, 2007). GSCM stresses more than just improving environmental performance; the implementation of green supply chain management can ensure that the corporation itself and its suppliers conform to environmental regulations. Effective management of suppliers can reduce transaction costs and promote recycling and reuse of raw materials. Also, the production of waste and hazardous substances can be cut, preventing corporations from being fined as a result of violating environmental regulations. Consequently, the relevant handling and operational cost involved can be further reduced and, in the meantime, the efficiency of using resources can be enhanced (Sarkis, 2003). Furthermore, adopting a sustainable approach can produce less waste and use more recycled material, thereby using energy, water, and by-products in a more efficient way (Tsoulfas and Pappis, 2006). Following the above discussions, the present study considers environmental performance to include two dimensions: management performance (environmental policies and measures, the approval rate of the management system, and the improvement in community relations and corporation image) and operational performance (the performance in using energy/resources, the reduction of emission, and waste disposal). After the above analyses, the researcher makes the following hypothesis:

Hypothesis 5: Eco-design has a positive relationship with environmental performance.

Economic Performance

Environmental protection activities can have a positive effect on a corporation’s financial performance. GSCM can cut the cost of materials purchasing and energy consumption, reduce the cost of waste treatment and discharge, and avoid a fine in the case of environmental accidents (Zhu and Sarkis, 2004). A sustainable approach can lead to internal cost saving, open new markets and find beneficial uses for waste (Tsoulfas and Pappis, 2006). Environmental munificence has a positive effect on financial performance (for example, growth in profits, sales, and market share) (Fuentes-Fuentes, *et al.*, 2004). Financial performance is defined here as cost reduction, market share growth, and profit increase. To analyse the research done by Zhu and Sarkis, et al. (2005), the researcher issues a hypothesis:

Hypothesis 6: Eco-design has a positive relationship with financial performance.

Research Methodology

The research is intended to cover an empirical analysis investigating key drivers of adopting Eco-design and its impact on organizational performance by leading edge companies to enhance their own environmental performance. This study conducted a survey to obtain quantitative data for statistical testing of the hypotheses.The survey was conducted using mail questionnaire. Mail questionnaire method was employed in this study because of its advantage of covering wide geographical area with less time and cost (*Sekaran, 2003*). A total of 150 questionnaires were sent out, and 91 valid responses were returned, a valid response rate of 60% was achieved.The unit of analysis of the study is the individual firm.

Choice of Industries

Primary data is collected from electronics industry of Noida. The electronic products industry is R&D-intensive with high value-added intermediate corporate products or consumer goods. The existing and potential environmental impacts of the products manufactured in that particular industry are substantial: for instance, the use of arsenic and lead in computer circuits, the amount of electrical energy necessary to operate refrigerators, or the waste problems created by the disposal of PCs (more than 10 million per year in the US only) The sample includes companies that export to overseas markets and/or provide raw materials or parts to manufacturing companies.

Data Analysis and Result

The respondents were asked to indicate their agreement or disagreement with survey instrument using a five-point Likert scale. The returned questionnaires were statistically analysed by a statistical software. First, the research instrument was assessed for its reliability and validity. Second, Descriptive statistics are applied to analyse the respondents' demographic data. Finally, the hypotheses were tested by multiple regression method.

Reliability and Validity Assessment

Goodness of measures was gauged in this study using validity and reliability tests. Exploratory factor analysis is used for testing the validity of measures of all the variables under study. The reliability or internal consistency of measures was tested using Cronbach's alpha test. The following subsections illustrate the results of factor and reliability tests. Factor analysis was performed in two parts one to identify the factors which are affecting adoption of Eco_design and other to identify the factors of organisational performance. The analysis starts with evaluating the appropriateness of the data or correlation matrix for factor analysis. The KMO measure should be at least 0.6 and Bartlett's test of spherecity should be significant ($p<.05$) (Hair *et al.*, 1998).

Factor Analysis

Factors Affecting Eco-design Practice

In this research, 9 items on a five-point scale (1 = Strongly disagree, 5 =Strongly agree) was used for measuring Factors affecting Eco-design practice including Environmental Policy, company features, market pressure. The items are shown in Table 2.

The scale items are based on existing literature on GSCM (Zhu and Cote, 2002; Zhu and Sarkis, 2004; Zsidisin and Hendrick, 1998). To measure overall factors PCA was used. The items for factor analysis are shown in Table 2. A factor analysis was conducted to further confirm grouping of factors affecting Eco-design from the survey data. Factors were extracted using the maximum likelihood method, followed by a varimax rotation.

Table 2

	Item
Environmental Policy	Domestic environmental regulations
	Government environmental Policy
	International environmental agreements
Company Features	Company size
	Commitment of individual employees (R and D)
	Companies are either certified to the EMAS scheme or the ISO 14001 standard
	Corporate Social Responsibility
Market Pressure	Customer pressure
	Supplier relationship

By inspecting the values in Table 3, the KMO measure of sampling adequacy is 0.718 and the Bartlett's test of spherecity is significant (p<.01) which indicates that the matrix meets the assumption of factor analysis and can be factorized.

Table 3

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.718
Bartlett's Test of Sphericity	Approx. Chi-Square	571.442
	df	36
	Sig.	0.000

Table 4 indicates that factors affecting Eco-design practice items load into three factors with eigen values exceeding 1. The three extracted factors matched the three conceptualized factors namely Environmental Policy, Company features, Market Pressure. Further analysis confirms the reliability of these three factors which is shown in Table 8

Organizational Performance

In this research, 12 items on a five-point scale (1 = strongly disagree, 5 =strongly agree) was used for measuring Organizational performance including Competitive advantage, Environmental performance, Economic Performance. The items are shown in table 5.

By inspecting the values in Table 6, the KMO measure of sampling adequacy is 0.692 and the Bartlett's test of spherecity is significant (p<.01) which indicates that the matrix meets the assumption of factor analysis and can be factorized

Table 7 indicates that Organizational performance items load into three factors with eigen values exceeding 1. The three extracted factors matched the three conceptualized factors namely Competitive Advantage, Environmental performance, Economic Performance Further analysis confirms the reliability of these three factors which is shown in Table 8

Reliability Analysis

Reliability analysis is conducted in this study to ensure that the measures of variables have internal consistency across time and across the various items that measure the same concept or variable

Table 4: Rotated Component Matrix[a]

	Component		
	1	2	3
Domestic environmental regulations	0.751		
Government environmental Policy	0.798		
International environmental agreements	0.842		
Company size		0.628	
Commitment of individual employees (R and D)		0.876	
Companies are either certified to the EMAS scheme or the ISO 14000 standard		0.901	
Corporate Social Responsibility		0.926	
Customer pressure			0.794
Supplier relationship			0.695

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

The gap on table represents loadings that are less than 0.6, this makes reading the table easier. All loadings less than 0.6 have been suppressed.

Table 5

	Item
Competitive advantage	Improving product quality
	Increasing efficiency
	Enhancing productivity
Environmental performance	Management Performance
	Operational performance
	Improvement in community relations and corporation image
	Performance in using energy/resources
	Reduction of emission
	Waste disposal
Economic Performance	Cost reduction
	Market share growth
	Profit Increase

Table 6

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.692
Bartlett's Test of Sphericity	Approx. Chi-Square	752.576
	df	66
	Sig.	0.000

Table 7: Rotated Component Matrix[a]

	Component		
	1	2	3
Improving product quality		0.775	
Increasing efficiency		0.855	
Enhancing productivity		0.876	
Management Performance	0.610		
Operational performance	0.842		
Improvement in community relations and corporation image	0.827		
Performance in using energy/resources	0.874		
Reduction of emission	0.601		
Waste disposal	0.709		
Cost reduction			0.701
Market share growth			0.912
Profit increase			0.765

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

The gap on table represents loadings that are less than 0.6, this makes reading the table easier. All loadings less than 0.6 have been suppressed.

Table 8: Reliability Assessment

Factor	No. of items	Cronbrach's alpha
Environmental Policy	3	0.703
Company Features	4	0.735
Market Pressure	2	0.887
Green Design	8	0.747
Competitive Advantage	3	0.726
Environment Performance	6	0.716
Economic Performance	3	0.753

(Sekaran, 2003). Reliability is measured in this study using Cronbach's alpha coefficients. The measures are considered to have sufficient level of reliability when Cronbach's alpha values equal to or greater than 0.70 (Nunally, 1978). Table 8 provides the values of Cronbach's alpha for the variables. It appears from the table that the values of Cronbach's alpha ranges between 0.703 and 0.887. These values well exceed the minimum value of 0.70. Thus, it can be concluded that the measures have acceptable level of reliability.

Descriptive Statistic

Table 9 shows the profile of respondents who answered the questionnaire. The table reveals that 60.4% of the respondents hold a position of manager (Operations Head) in their firms and are attached to the operations or production department (60.4%). Regarding the experience of respondents

Table 9: Profile of Respondents and Firms

	Frequency	Percent
Designation		
Supply Chain Manager	27	29
Assistant Manager	9	9.9
Operations Head	55	60.4
Department		
R & D	9	9.9
Operations	55	60.4
Quality Control	27	29.7
No. of Years		
6-10	9	9.9
11-15	54	59.3
> 15	28	30.8
Qualification		
PG	18	19.8
UG	64	70.3
Diploma	9	9.9
Gender		
Male	73	80.2
Female	18	19.8
Age		
20-30	14	15.4
31-40	42	46.2
41-50	29	31.9
51 and above	6	6.5
No. of Employees		
≤ 200	9	9
201-400	18	19.8
401-600	45	49.5
> 600	19	20.9
No. of Suppliers		
≤ 10 suppliers	18	19.8
> 10 suppliers	73	80.2
Supplier Relationship Length		
1-5 years	9	9.9
More than 5 years	82	90.1
Customer Relationship Length		
1-5 Years	9	9.9
More than 5 years	82	90.1
Green Association		
Yes	62	68.1
No	29	31.8

in their firms, the data reveals that about 59.3% have more than fifteen years of work in their firm, which indicates that the respondents were selected from the most experienced persons in their firms. Similarly, the table shows that 70.3% of the respondents hold graduate degrees. The data shows also that 80.2% of the respondents are male and 19.8% are female. Lastly, the table reveals that most respondents are in the middle range age (30-50 years) (46.2%). The table also shows that most firms are considered large firms (more than 400 employees) (about 50%). Finally, more than half of the firms (68.1%) participate in industry trade or professional associations that have interest in green issues.

Analysis

Results of Regression of Eco-Design on factors affecting Eco-design

Multiple Regression Analysis

Multiple regression analysis was used to test the research hypotheses. Multicollinearlity problem was evaluated by variance inflation factor (VIF). Theoretically, if the VIF value is lower than 10 it means that there is no relationship between the variables. To test hypothesis 1, hypothesis 2, and hypothesis 3, the author regressed Eco-Design parameter on factors affecting its adoption including Environment policy, Company features, Market Pressure.

Table 10

	Coefficients[a]						
	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (Constant)	1.346	0.271		4.965	0.000		
Environment policy	0.287	0.071	0.314	4.034	0.000	0.667	1.499
Company features	0.178	0.067	0.233	2.657	0.009	0.524	1.908
Market_Pressure	0.153	0.028	0.433	5.525	0.000	0.655	1.527

a. Dependent Variable: Eco_Design

** $P < 0.05$ $R = 0.806$ $R2 = 0.650$ $F = 53.74$ Sig. = 0.000**

The results of the questionnaire survey are presented in Table 10.

Hypothesis 1: From Table 10, Environment policy is found to have the positive âeta of 0.314 at p = 0.000*. It can be seen that Environment policy has significant positive relationship with Eco-Design. Therefore, hypothesis 1 is accepted.

Hypothesis 2: From Table 10, Company features is found to have the positive âeta of 0.233 at p = 0.000*. It can be seen that Company features has significant positive relationship with Eco-Design. Therefore, hypothesis 2 is accepted.

Hypothesis 3: From Table 10, Market Pressure is found to have the positive âeta of 0.433 at p = 0.000*. It can be seen that Market Pressure has significant positive relationship with Eco-Design. Therefore, hypothesis 3 is accepted.

Results of Regression of Competitive advantage on Eco-design

Hypothesis 4: From Table 11, Eco_design is found to have the positive âeta of 0.609 at p = 0.000*. It can be seen that Eco_design has significant positive relationship with competitive advantage. Therefore, hypothesis 4 is accepted.

Table 11

	Coefficients[a]						
	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (Constant)	0.020	0.567		0.035	0.972		
Eco_Design	1.050	0.145	0.609	7.237	0.000	1.000	1.000

a. Dependent Variable: Competitive advantage

** P < 0.05 R = 0.609 R2= 0,.370 F = 52.379Sig. = 0.000**

Results of Regression of Environment Performance on Eco-design

Hypothesis 5: From Table 12, Eco_design is found to have the positive âeta of 0.794 at p = 0.000*. It can be seen that Eco_design has significant positive relationship with Environment Performance. Therefore, hypothesis 5 is accepted.

Table 12

	Coefficients[a]						
	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (Constant)	1.166	0.228		5.120	0.000		
Eco_Design	0.719	0.058	0.794	12.337	0.000	1.000	1.000

a. Dependent Variable: Environment Performance

** P < 0.05 R = 0.794[a] R2 = 0..631 F = 152.197Sig. = 0.000**

Results of Regression of Economic Performance on Eco-design

Hypothesis 6: From Table 13, Eco_design is found to have the positive âeta of 0.604 at p = 0.000*. It can be seen that Eco_design has significant positive relationship with Economic_Performance. Therefore hypothesis 6 is accepted.

Table 13

	Coefficients[a]						
	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (Constant)	1.035	0.466		2.219	0.029		
Eco_Design	0.852	0.119	0.604	7.141	0.000	1.000	1.000

a. Dependent Variable: Economic_Performance

** P < 0.05 R = 0..604[a] R2 = 0..364 F = 50.996Sig. = 0.000**

Conclusion

The purpose of this study was to identify the relationship between eco-design and its factors including environmental, market and company pressure and further to identify the relationship between eco-design and organisational performance including competitive advantage, economic performance, and environmental performance. To test hypotheses, PCA and multiple regression method were conducted. Existing body of literature indicates that Eco design is positively related with above mentioned three factors and it is positively related with organisational performance.

The result was evidenced also by the result that firms with large number of suppliers adopt more Eco design than firms with lower number of suppliers. Large number of suppliers indicates that a firm is large is size. This result implies that large firms adopt more green supply chain initiatives than smaller firms. Large firms are generally having more resources and capabilities than smaller firms which enable them to attempt costly and/or risky environmental investments (Bowen, 2002). Larger firms are also more visible in society that induces them to adhere to environmental standards so as not to lose stakeholder support (Bowen, 2002). The study also found that firms participate in green associations adopted higher green supply chain initiatives than firms that do not participate. From these associations firms learn principles and standards of green initiatives as well as benefits and value of such initiatives. This increases the level of awareness of green issues among organizations and, subsequently, level of adoption. DiMaggio and Powell (1983) mentioned professional and trade associations as important vehicle for the definition and promulgation of normative rules about organizational and professional behaviour. However, this research is not without limitation. One clear limitation is the small sample size which causes limitation on generalisability. Future research should collect data from a more diverse sample.

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