

Environmental design within the Korean electronics industry

- With particular reference to handheld devices

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I. Abstract

The paper will examine the use of eco-design tools within the Korean electronics industry, with particular reference to mobile phone design & manufacture.

Economic growth in Korea has been driven by aggressively exporting products, primarily to the US & China. Industries - such as semiconductor fabrication & electronic products - have been at the forefront of this export strategy.

With impending environmental legislation threatening many of Korea's global export markets, this study represents a timely appraisal of the industry's ability to respond.

The paper goes on to consider the extent to which eco-design tools are implemented within the Korean electronics industry, & which are most appropriate in environmental and business perspective. Whilst a simple question, this demands a non-trivial set of answers, each step posing significant problems. This is conditional on both the relevant environmental protocol for each market region, & the development of a means of cross-comparing what are very different metrics of environmental damage.

In resolving this, the paper adopts Eco (or Fussler's) Compass as a graphical representation, & uses this to evaluate the impact of a range of concepts, developed using each of the identified design tools, & based on Lifecycle Analysis (LCA-environmental quantitative evaluations method).

The paper concludes by presenting cross comparing in environmental effectiveness against business and major international environmental legislations, ranking each of the tools against eco-benefit, relevance to a particular region/market & cost to the organisation, the latter being measured in times of: current capability; required investment in process; requisite developments in technology (R&D investment &/or licensing); & anticipated problems in cultural adaptation.

I. ABSTRACT

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Chapter 1. Introduction

1.1 Research Background

Historically environmental design or environmental product development are frequently undertaken, however when comparing the efforts of designers and manufacturers not many successful achievements exist (Edwin Datschefski, 2000).

According to previous research, change the Earth's climate is caused by human activities and is serious and issues need resolving urgently (David Archer & Stefan Rahmstorf, 2010). Most climate models demonstrate that doubling pre-industrial levels of greenhouse gas is very likely to commit the Earth to raise between 2~5 °C in global temperature (Stern review 2013). This research shows that this increased level of greenhouse gas will become a significant risk element to human societies between 2030 and 2060 (David Archer & Stefan Rahmstorf, 2010). Also in this report, a warming of 5°C on a global scale would be far outside the experience of human civilisation and comparable to the difference between temperatures during the last ice age and today, which will produce serious environmental change to the Earth; these circumstances may influence human civilisation (Stern review 2013).

In previous research, a few economists and environmentalists have asserted that these climate changes would be one of the biggest factors in shifting the markets and industrial structures (Anand and Sen, 2000). However, the combination between economics and climate change or any environmental issue may be broad ranging, deep and complicated similar to any other area of economics (Stern review, 2013). This requires i) no margin policy, ii) huge economic risks taking and uncertainty, and iii) needs long term evaluation and A discount policy for dealing with long-run impacts of climate change impacts (Stern review, 2013). Why do economists assert the necessities of economic needs when reviewing environmental issues?

According to Jacobs (1991), he asserted that environmental industries traditionally cut the costs for reducing emissions and the management of industrial waste, which have become serious industries, however when developing alternative energy and

the management of energy consumption, emission materials have become a key factor in deciding a companies' market success. These types of new environmental industries have developed in the modern society, which focuses on 'efficiency' and have generated demands on environmental, social and market trends. Hannah's previous study regarding historical achievement of the UK electricity industry, for example, reports that the consumption of coal was 10-25 lbs / kWh in 1891, 5 lbs / kWh in the first decade of the 20th century and 1.5 lbs / kWh by 1947; today it is about 0.7 lbs / kWh, this is roughly a 10-fold increase over the century in the efficiency of power generation alone (Neil Cater, 2011). Despite the existence of technology and industry in modern society that requires more power supplies, such numerical value means the increase in efficiency of resources by 36 times more compared to what had been consumed in 1891.

These results have been impressive achievements in efficiency with energy utilised for heating, lighting, refrigeration and motive power for industries and transportation (Jacobs, 1991). Referring to this report, to achieve these environmental successes required reflecting on users' demands within usage time and developing solutions for dealing with these demands. New products also became more efficient; such as the invention of double-glazing, the use of 'natural' systems for lighting and substitution of gas for coal for heating (Jacobs, 1991).

Other issues include internal and external pressures such as international environmental legislation and market demands, which have become significant market drivers. Therefore, when implementing environmental projects many countries set up expert groups and think-tanks.

For example, in 2006, the UK launched the Energy Technologies Institute (ETI). It is funded on a 50:50 basis between private companies and the public sector with the government prepared to provide £500 million, creating the potential for a £1 billion institute over a minimum lifetime of ten years (Stern review 2013). These organisations will undertake to find innovative ways to balance environmental and economic benefit through research and policy suggestions.

In conclusion, the Earth's climate change is the most significant factor to threaten human civilisation, but also this will produce new opportunities for industrial, economic and environmental preservation through dealing with these complex problems.

Therefore, in this study, eco design methodology, which takes serious considerations in modern industry due to the accrued environment contamination, is applied in mobile phone development process then practicality will be verified and the value of this investigation would propose the construction of quantitative as well as qualitative eco template not only in mobile phones but in electronic products in near future.

1.2 The Aims of the Study

This research reviews various barriers for eco design and eco products, which although designers recognise the importance and necessity, however there are still not many successful designs or achievements through this method. The research will suggest new approaches for applying quantitative methods for qualitative use and show the advantages and difficulties of various eco design tools through comparison and pilot studies.

This will also compare eco design tools by environmental and business standards to use in manufacturing areas.

To investigate these issues, this research has two key questions / objectives:

- i. What kind of environment friendly or sustainable design methodology could affect mobile phone development? / What kind of effects could Environment friendly or sustainable design methodology make on mobile phone development?
 - To establish the effectiveness of differing sustainable design approaches on the development of mobile phones;

ii. Would environmentally high valued eco-friendly design methodology be highly valued in business as well? / What difference could environmental value and business value make? / Due to what elements do such difference is caused?

- To compare the results between (i) ecological benefits from LCA and Eco compass and make recommendations to the industry re the adoption of eco-design tools

This research will show new guidelines to deal with eco design barriers faced by manufacturing companies including Korean companies. Various problems such as can be occurred by different gaps between industrial and eco design approaches at the design stage are i) difficulties in interpreting engineering materials for LCA results, ii) difficulties implementing long term and sophisticated projects; eco product development normally demands ecological solutions by applying new or better materials and also needs to consider ecologically innovated materials more than with general product development, and iii) also show the various feedback from different areas within the company such as marketing, engineering and design when product development is undertaken by eco design tools by implementing design work that applies eco design tools to the object, evaluations and interviews.

These questions in this study means to search the connections between i) the industrial designer's shortage of performance competence in eco-friendly design and ii) business enterprises. Although various eco-friendly designs have been attempted previously, many successful cases are neglected and disregarded. For such matters, this study has been aimed at Korea's mobile phone industry – A single product group (chapter3) which influences vastly in environment and research target that shows the most productivity in this field of industry.

1.3 Introduction and Scope

Economic growth in Korea has been driven by aggressive exports, primarily to the US and China. The semiconductor (\$33.6 billion, 21.9%) and electronics industries - \$33.6 billion and 21.9% of the economy - have led the growth in this area (Economist, 2009). Korea now has the 12th largest economy, incorporating some of the largest

global companies (¹chaebols) – typified by Samsung, LG, SK and Hyundai. However, the potential negative impact of poor sustainability is becoming one of the key drivers in forcing Korean blue chip brands to reconsider their development policies.

Greater emphasis has been placed on positive ethical business strategies, exemplified by the “Triple Bottom Line” (McDunough, 2002, p.154) concept – which seeks to achieve a balance of social, economic and environmental issues. Companies such as Samsung, who have invested in developing high-end technologies and product applications, need to develop more effective sustainable product development policies against the threat of brand erosion. The challenges this represents for design managers requires the acquisition of new knowledge tools with which to form appropriate strategies.

This is particularly critical where pro-environmental policies are now acting as potential trade-walls. European directives such as the End of Life Directive; EVL (2000) and Waste Electrical and Electronic Equipment; WEEE (2003, and enforced from 2007) have already had an impact (Simon Mingay, Gartner Report, Green IT: The New Industry Shock Wave, 2007). Recent regulations such as the Basel Convention, Kyoto Protocol, Reduction of Hazardous Substances; RoHS, and the United Nations Framework Convention on Climate Change - have influenced the industry massively, both directly and indirectly, using mass media to inform consumers as to the importance of environmental technology (Mingay, 2007).

From this context, the mobile phone sector has been chosen as typical of the high technology electronics industry, and the trend towards media convergence. It is a ubiquitous technology dependent on the extensive use of toxic materials in fabrication. It also represents an expanding global market with a proliferation of models, and high consumption and disposal rates (typically less than a one year life, dictated by network provider contracts). Further, a number of key Korean manufacturers have an extensive interest in the sector.

¹ Chaebol is a company, which has more than 5-6 sub-companies and pass on power to CEO's descendants (Oxford Dictionary).

In case of selected Korea's mobile phone industry in this study, as it will be referred in chapter 3, each mobile phone's physical size does not differ much from other electronic products, however considering the output, the amount being used, the number of mobile phones and the amount of mobile phones that are discarded, it shows the highest growth as well as the most discarded as a single product. Along with this, according to the GATT report 2013, Samsung and LG has been ranked first and third as of 2013 1-4 quarters that created the most mobile phones, which demonstrates that the Korea's mobile phone industry already has been internationalized.

There is growing realisation in Korea that it cannot continue to grow without considering the development of sustainable design strategies (SamOk Park, SeungMok Yang, 2009) Whilst discussions regarding ecological and sustainable design are still at a very embryonic stage, this research is focused on understanding how Korean electronics companies can positively respond to these demands.

Interviews with senior managers across a number of larger producers identified three significant issues which form part of this 21st century paradigm: design and technology needs to be ubiquitous, universal and environmentally-friendly.

In contrast, primary interviews in the early stages of research undertaken by the author with in-house designers indicate that a key statement to study it indicates few companies are families with environmental polities and fewer still are familiar with the use eco design tools this is a key statement in study, indicating that most environmental projects are either outsourced or restricted to engineering, rather than developed by in-house specialist design teams.

Moreover, the interviews for the current roll of eco policies are only advertisements or public relationship such as green washing (<http://www.greenwashingindex.com>, access date: 10, April, 2013) and also the author found knowledge gaps on eco design between the level of positions and different working areas (see chapter 7).

During this survey, the author found that they only adopted LCA for eco design development in R&D however this method is not for developing design and the design teams only mentioned 3 key issues; emotional, aesthetic and technical fulfilment.

To sum up, CEOs or directors have recognised that an eco-design status is essential in reinforcing global eco regulations. However, designers cannot undertake this subject because i) there are no bridges between the CEO and designer, ii) companies still focus on new technologies, iii) they also think that developing eco product requires huge investment and iv) they haven't got any eco design experts.

1.4 Timeliness of this research

This section will present the time relevance of this research for various perspectives. These can be explained through several significant issues which are i) environmental necessity through serious environmental erosion, ii) increasing environmental concerns of international organisations, iii) the development of international environmental regulations, iv) new market demands through growing awareness of social environments and v) new environmental paradigms that achieve eco products through secure environmental high technologies.

These issues have cause and effect relationships (chapter 3) and the reasons for raising these issues at this time solve physical eco problems within the environment which have become significantly serious enough to think only in economic terms (chapter 9). Such cause and effect relationship is the demand in various eco-friendliness, namely consistently deteriorating environmental demands and in accordance with inevitably occurring and strengthening international environmental legislations' social influences are formed through market. As this environmental necessity in the market has come fore, enterprises have been located in situation where they launch eco-friendly products, which involves economical profit.

Moreover, environmental issues have become the blue chip in the twenty first century through consumer ecological demands, which have moved closer to new

market standards where environmental issues do not only depend on public principles but also on international standards.

1.4.1 Necessities for environmental preservations

According to 'The Science and Politics of Global Climate Change (Dessler and Parson, 2010)', the answers regarding 'does human life influences the earth's climate change?' would be difficult because before establishing the industrial civilisation, the climate change was delicate and slow. However, the problem is that the speed of climate change has accelerated faster than developing civilisations and establishing industrial societies.

According to 'Introduction to Modern Climate Change (Dessler, 2011)' the average surface air temperature increased about 0.7 Celsius degrees over the twentieth century, with the rate of warming in the last half of the century about twice the rate of the first half.

Glaciers have been receding worldwide for the last two centuries, with evidence of faster retreat in the twentieth century. Sea levels have raised about seventeen centimetres total over the twentieth century, with the rate of increase accelerating in recent decades. The area of Arctic sea ice has decreased by two point seven percent per decade over the past thirty years, with decrease in summertime minimum area of seven point four percent per decade. The average thickness of Arctic sea ice has also decreased over this time.

The Earth's temperature was higher during the last few decades of the twentieth century than during any comparable period during the last four hundred years (Dessler, 2011)

1.4.2 Pressures from international organisations

GATT (General Agreement on Tariffs and Trade) and the WTO (World Trade Organisation) announced that eco regulations only have to work on environmental

preservation or related eco issues, they will review advanced countries' behaviour for example, when using eco regulations for unfair trading or for judging the national legitimacy (GATT report, 2009). However many developing countries asserted that developing eco regulations mostly based on economic and environmental benefit and also most international groups developed eco regulations at the same level between advanced and developing countries in line with UN eco policies specified. These compare production activities and consumption in advanced and developing countries, and impose a duty on these therefore creating a level playing field.

Moreover, consumers' concerns for eco products in Korea is a target area in this research, which have been rapidly increasing, over 85% of the entire economic activities (SangOk Park, SeungMok Yang, 2009) are implemented through trading exports and imports (see chapter 2).

According to Korean news (Seoul Newspaper 2008), Korea has to accept economic politics from a manufacturing benefit for environmental advantage because eco-benefit is not only a selective activity but also an essential factor for trading, particularly within the Free Trade Agreement (FTA). From 2010, Korea has succeeded in the FTA with Chile, Nepal, EU and USA. However many economists have raised several key issues related to eco regulations. Therefore, Korean markets have to be sensitive with regard to various international environmental regulations for example, during concluding the FTA with EU, the environmental issues were the biggest issues.

The major products within the FTA were electronic products and automobiles and WEEE and RoHS, which are currently the strongest international environmental regulations in the EU impact on those industries directly. Furthermore, environmental technologies such as water management technologies and products, water purification systems and waste management technologies were involved in FTA and those have become a powerful export item. Consequently, the Korean government, local autonomous entities and manufacturing companies have increased investment to develop environmental technologies and products.

Comparing the Korean national environmental policies to other advanced countries such as the UK and Japan within the environment has been poor because Korea has only focused on economic growth for forty years; therefore many Korean CEOs and governors still concentrate only on economic value rather than environmental preservation (SangRyul Chung, 2006).

The level for dealing with environmental problems in Korea ranked tenth in Organization for Economic Cooperation and Development (OECD) however for the level of Environmental Sustainability index (ESI), Korea was situated at the bottom. This means that the Korean national market policies have to deal with environmental problems and contributory activities, and in contrast, the strong international environmental regulations and restrictions centred on the EU may not work effectively. Therefore, the Korean government have recognised this with recent environmental issues connected to economic benefit and have developed and proclaimed new national environmental policies, which are more focused on market mechanisms from 2005.

Recently, consumers and markets have been the most significant factors in corporate management, especially for undertaking 'Sustainable development and consumption', which needs to balance the consumer, NGOs, corporate and government. The global market, government and international organisations have been asked to improve their eco requirements with aggressive effort. This helped to develop new economic issues, from the private economic structure centring on government. The role of the consumer has changed to a major critical group (SangRyul Chung, 2006).

1.4.3 Markets demand 'Green product'

In the 21st century, consumer groups, NGOs, providers and government recognised the necessity for environmental preservation and have tried to find better solutions, therefore these requirements stimulated the establishment of the concept of sustainable development and consumption. The concept started from consumers who wanted to achieve spiritual satisfaction rather than physical fulfilment through

ecological consumption such as green consumers, however this contained contradictory concepts, solving the environmental preservations though consumption (Chen Zhuanqing, 2006), that means achieving higher level of Consumerism should be undertaken through making social and ecological balance by promoting national prosperity by consumers and companies' mutual efforts (Chen Zhuanqing, 2006). Consequently, increasing consumer's concerns for the environment provided a turning point from an original marketing concept to green marketing.

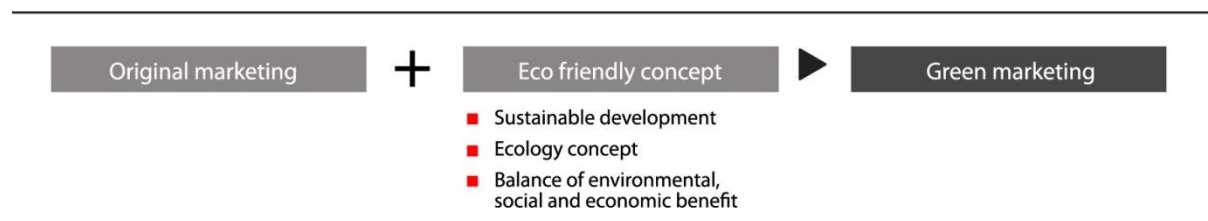


Figure 1.1 Concept of Green marketing (JungWoo An, ByungOk Cho, 2005)

The definition of Green marketing is not only focused on the concerns of consumers' demands and physical satisfaction but also considers ways of increasing environmental awareness and balancing environmental and social benefits to achieve quality of lifestyle improvement. This concept not only concerns a single side of benefit rather it considers balancing consumers (social), companies (economic) and environmental (ecological) benefits through reflected market demands. Green marketing is also more focused on consumer's long-term satisfaction by improving life environments and these aspects stimulate corporates policies to adapt to improved environmental perspectives.

	Economic marketing approach	Green marketing approach
Basic Concept	Consumer's and corporates benefits (Concept of economic balancing benefit)	Balancing of ecological, social (people's) and providers (corporates) benefits (Concept of social and ecological balancing benefit)
Sense of Value	<ul style="list-style-type: none"> • Achievement enhancement by providing physical wealth (Economic value) • Aiming to economic achievement 	<ul style="list-style-type: none"> • Improving 'quality of lifestyle' by providing social benefits (Public welfare value) • Considering entire members in society and

	through market share, corporate profit and increasing sales (Maximization principle)	environments (Optimization principle)
Feature	Corporate system generate marketing values	Social awareness generate marketing values

Table 1.1 Comparing traditional and Green marketing concepts (Korea Institute of Industrial Technology, 2012)

Especially, in the case of green marketing, it is based on provider's environmental responsibilities, therefore it requires social indemnifications when environmental issues occurred by defective product and riskiness.

This issue has given pressure to the providers because various toxicities and invisible riskiness can occur in every stage of the entire product lifespan. The significant impacts of these international restrictions are not only direct restrictions such as financial sanctions but indirect effects such as image risks, which are more powerful restrictions (chapter 2). Therefore, these have led to new environmental trading rounds, where companies take a positive place in the market through effectively dealing with these regulations.

According to Shao Jihong at el (2010), green marketing has currently become the representative model for the Corporate Social Responsibility (CSR) and these aspects have been more significant issues, as green issues became the competitive factors. The driving force of green marketing growth, not only considers economic benefits. This can be refuted by traditional marketing principles and the biggest differentiation of green marketing is balancing the benefits for people's lifestyles such as consumer health, environmental advantage and economic benefit from a long-term perspective. Green marketing cannot produce immediate results but green marketing has a higher priority regarding increasing the consumer's loyalty and the amount of regular customers (Shao Jihong at el, 2010)

Recently, green marketing has been undertaken in manufacturing centred companies because the companies' responsibilities will be strengthened and markets and consumer's demands will be segmented and diversified as time passes. Therefore, applying eco design methods to the product development in this research

will present results on how to fulfil environmental and economic demands through adopting appropriate eco design methods.

1.4.4 Rapidly increasing environmental friendly technologies

A global movement of environmental policies has been more focused on providers' responsibilities. According to McDonough (2002), these current international policies and regulations require provider's responsibilities from production level to disposal and recycling level.

This phenomenon has only occurred in advanced countries, the EU and US are leading international environmental regulations but also developing countries have had more influence because environmental restrictions have become the fundamental factors in economic growth activities recently.

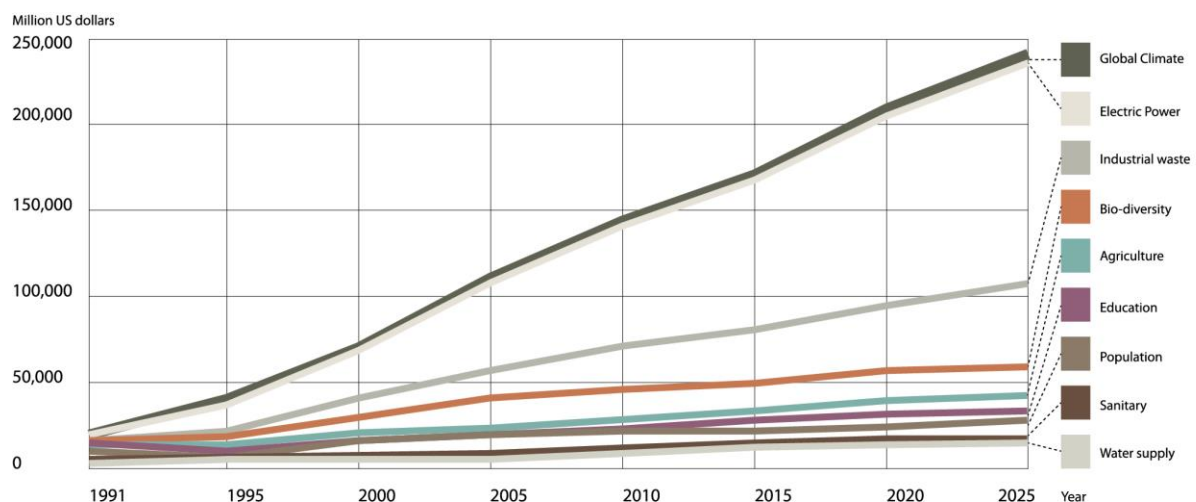


Figure 1.2 Demand for environment-related funding in the Asia-Pacific region (ECO ASIA; Environment Congress for Asia and the Pacific, 2008)

Figure 1.2 shows mostly that Asian-Pacific countries have increased environmental investment and demands, and the distinct factors with advanced countries environmental investment that these developing countries are only investing in particular environmental sectors that are related to major industries or government policies (ECO ASIA; Environment Congress for Asia and the Pacific, 2008).

By all means, above graph does not have a direct relation to this study but through this graph, countries in Asia (as most of them are developing countries, apart from electronic products and automobile fields, Korea is considered to be advanced developing country (Sang Ryul Chung, 2006) also invest vastly on eco-friendly section and this investment rate is rapidly increasing.

Furthermore, the transfer of environmental technology from other countries should not be a matter of mere reliance on aid or import; it is vital to use this technology to promote domestic industry, and also to induce a synergy between environmental investment and economic growth (ECO ASIA; Environment Congress for Asia and the Pacific, 2008).

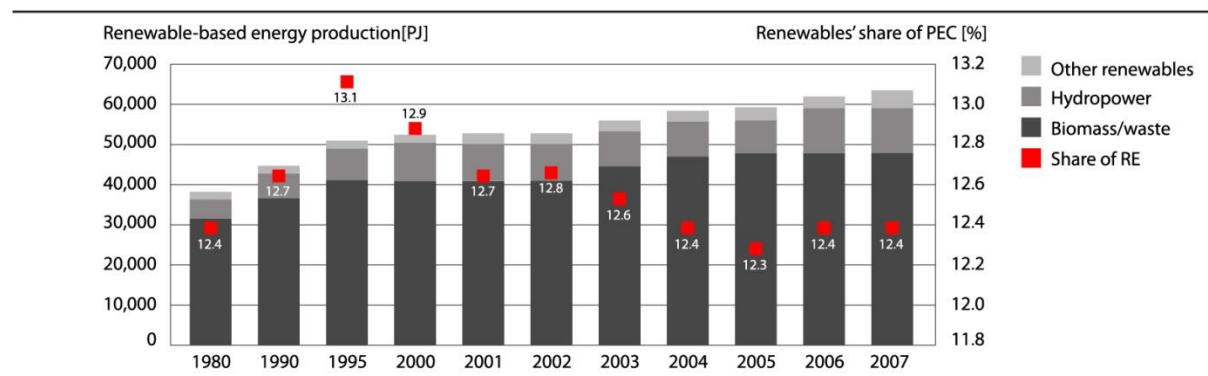


Figure 1.3 Amount of production and consumption of global renewable energy (International Energy Agency (IEA) outlook, 2011)

This graph presents the rates of using natural energy or renewable energy which have increased steadily and particularly when using Biomass, had a turning point in 1995. Biomass means organic materials or living organisms of the natural world. Biomass materials can be the longest lasting in history, however this has an underestimated value when comparing fossil fuels such as oil and coal, which are convenient to use and provide wide reaching service (LG annual economic, 2009).

Since 1995, when soaring oil prices influenced the investment in the renewable energy industry and Biomass industry in renewable energy sources, recorded the highest rates of growth since 2000. Moreover, taking the Kyoto protocol effect, companies and countries have tried to develop alternative energy technologies and secure resources to deal with such issues, Biomass, which is using the waste from

agricultural by-product has become accepted as an effective current solution (LG annual economic, 2009).

Particularly, using renewable energies, which are produced by clean technologies, used sixteen percent of the total energy consumption globally (2006) and the UN estimated energy crisis should be developed without extending the use of renewable energy and developing alternative energy.

As this example demonstrates, environmental technologies have potential abilities to change the structure of industries and economies. Although people have been aware of the serious environmental problems for some time, recent environmental technologies such as alternative energy and renewable material have achieved environmental inspirations. In the design area, these achievements have occurred through the integration of high technologies in one-shot projects for example, Blue Earth phone (Samsung, 2010) used waste Pet bottles for 70% of their phone bodies and it also used solar power to charge the battery, which showed a new eco product paradigm. In contrast, this product was a sensation when it was launched to market but comparing its reputations to economic and social perspective, this product did not achieve success.

To achieve the economic and environmental benefits through eco design, the companies and clients have to invest in the long-term and apply the best design approaches, which are considered a balance of economic, environmental and social benefits (Willard, 2002).

1.5 Purpose of the Research

The purpose of this research was to study and compare the different appropriateness of eco design methods in an environmental and business perspective. Through this approach, the research will consider the causes of isolations of applying eco design methods into industry and develop suggestions for each area.

The research purpose will be defined in an environmental / business perspective.

- The purpose in an environmental perspective:

1) The research will demonstrate theoretical resource that find appropriate methods in particular industries for undertaking effective eco product development

2) This research will exemplify longer-term types of eco design rather than current eco design trends, which are focused on package design or applying recyclable materials.

3) This thesis will suggest applying conceptual ecological evaluation process to the design results and this will increase environmental reliability and industrial designer will be able to attain ecological confidence with their own design results.

- The purpose from a business perspective:

1) This thesis will define and categorise the eco design methods. This research will provide fundamental data for selecting the eco design methods when companies undertake eco product development in differing sector areas within a company such as marketing, production, design and senior management.

2) This research will deduct that there are significant gaps between environmental and business perspectives in applying eco design methods and will present the limitations of current eco design methods and essential factors in each areas within a company.

This research will also find various historical reasons for not using eco design methods by industrial designers despite social and environmental demands and will consider the eco design process from a designer perspective.

1.6 Research Methodologies

The methodologies used in this research will be practical design stage - design exercise for generating design concepts and theoretical analysing stage - ecological evaluation for finding environmental appropriateness (more information in chapter 5). To increase reliability, this research will establish the guidelines for design exercise and standards for selecting the eco design methods (chapter 3 and 5), and also the author will also develop various networks including i) eco experts, to effectively implement environmental quantitative and qualitative evaluations to design results (chapters 5 and 7) and ii) workers in different areas, to compare the appropriateness in a business perspective (chapter 8).

1.7 Definition of this research

This section will illustrate the purpose and direction of this research through defining eco design by comparing historical eco design concepts and traditional eco design definitions. In 1869, Ernst Haeckel created word that is 'ecology' and defined it as a type of science for studying relationships between life and the environment. Early concepts of ecology were used only in the natural sciences and this word originated from 'Oikos' meaning 'House' or 'Life' in Greek (Sun Ok Choi, 2006). According to traditional eco design, a reference by McHarg (1992) in 'Design with Nature', the environment is the highest priority for maintaining human civilisation. Despite this man has destroyed the environment through developing civilisations, however the environmental preservation is an essential factor for civilisation and in contrast, destroying the environment will destroy human civilisation.

Victor Papanek (1985 – original version 1971), who initially asserted designer's social and environmental responsibility from a designer perspective, emphasised in 'Design for the real world (1985)' that if man does not learn environmental preservation and the earth's resources and do not change the fundamental patterns re consumption, use and production then the ideal future will not exist.

Victor also asserted that designers should not hesitate to stand against environmental destruction and should find ways to recover the environment. This thought influenced the establishment of entire concepts for environmentally friendly design including eco design and impacted the designer's environmental and social responsibilities. Using more definitions from Maxwell and Van der Vorst (2003), Eco design (or Eco-design, Design for environment) is getting popular because the importance of awareness of environmental preservations is increasing, partly due to legislative pressure. Other definition from Kobayashi in 2006, 'eco design is the process of taking environmental impacts into design consideration that could result in environmentally conscious products. It is of vital importance to adopt this kind of philosophy as early as possible in any product development cycle.'

With previous definitions, the traditional definition of eco design, emphasises designer's responsibilities and roles. The dictionary definition of eco design is 'considering environmental direct and indirect impacts within the product lifespan' and this means that eco design is not only focusing on the production or disposal level but also considering potential environmental impacts during the entire product lifespan and related service (Davey, Wootton et al , 2004). These facts can be implied to shifting the environmentally friendly paradigm from emphasising consumers' responsibilities to manufacturers' or providers' during the product lifespan in production, usage, disposal and recycling. Hence, to achieve these conditions, eco designers have to understand a wide range of environmental positive and negative impacts that can occur through intended or unintended actions during a product lifetime.

Fiksel defined eco design as considering the safety of the environment during product lifespans (1993), the Rathenau Institute, promotes the formation of political and public opinion on science and technology in the Netherland and defined eco design as a merged environmental benefit to the product planning (1997) and Chater and Tischner also defined eco design as the consideration of the total product design process and planning based on the entire product lifespan (Calthorpe P, 1993).

In conclusion, to implement eco design, the designer has to consider all product lifespan and services related to eco design and distinguish concepts with other environmentally friendly design areas; i) eco design reflected recent global environmental friendly issues in shifting objects from consumer to providers, ii) this concept has to consider all product lifetime and iii) eco design concepts have to start from the design planning stage or the early level of product development.

The author asserts that the eco design concept requires combining sustainable TBL (Triple Bottom Line) concepts, which considers the balance between social (people), environmental and economic benefit. John Elkington created the TBL concept and Sustainability in reporting 'Our Common Future' (1987) in the Bruntland Commission.

This concept defines that eco design produces new environmental systems in halting the destruction of the current environment and environmental improvement to fulfil social satisfaction without physical innovation to maintain human life. This concept provides the fundamental idea that combines environmental benefits within the entire product lifespan and economic benefits to help find the appropriate eco design methods. Consequently, the definition of eco design in this research is to; i) consider the entire product lifespan, ii) influence various environmental issues, iii) connect economic benefits for sustainable achievement and iv) start eco design from very early stage product developing processes.

1.8 Findings of this research

The findings of this research will be shown in chapter 9 (Findings of research results). Figure 1.4 illustrates the findings framework for generating the research results. The research results will be produced in two different areas; appropriateness of environmental and business aspects which will estimate shifting eco scoring by size of investment increases. Through these research implementations, it will demonstrate the most effective eco design methods with different business phases, and a reflected range of investment and contexts of the product development process.

Reviewing this process, the author adopted UL110 to apply weight to the factors in eco compass at phase A1. UL 110 is a significant research material for environmental weighting and this standard is based on the eco compass. The UL110 standard was developed by the US environmental standards agency (more information in chapter 8). Phase A2 analyses eight eco design methods, which will apply to the design object by LCA (chapter 7). In conclusion, completing phase A2 will present Eco compass results regarding environmental effectiveness of eco design methods when applied to mobile phone design.

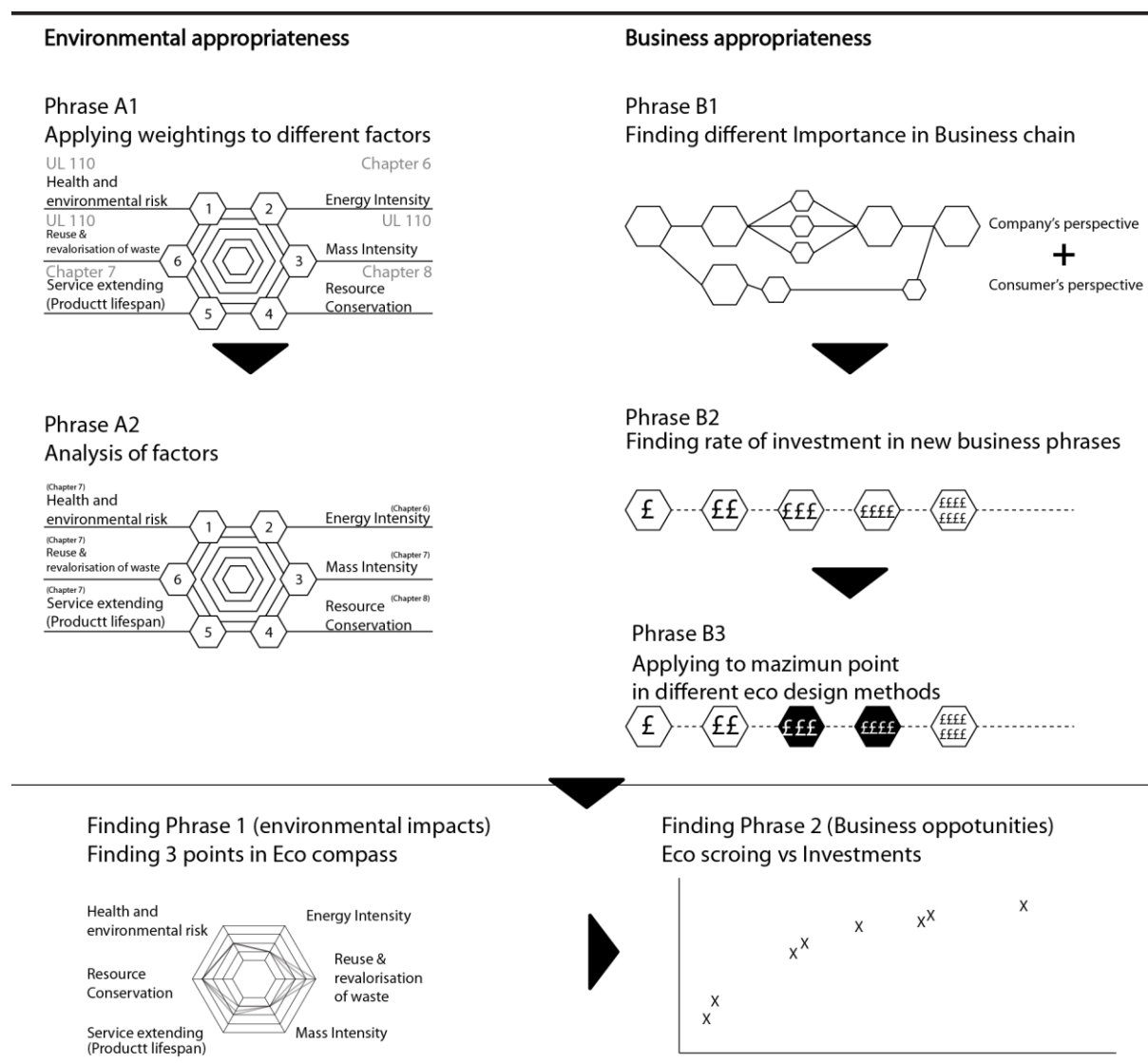


Figure 1.4 Findings framework

Above figure 1.4 is an access method for research finding which divides into two; Phase A that analyses environmental effects of eco-friendly design methodology and

Phase B that analyses business effects. Firstly in case of Phase A1, environmental impact data that has been drawn out from the quantitative research in this study is substituted based on Eco Compass and then it has been visually analyzed in Phase A2. Such series of work is for designers to have professional semiotic visual analysis that each eco-friendly design methodology shows separate strength and weakness on Eco Compass through quantitative and qualitative analysis. In case of Phase B1, business's link is visualized, which is divided into arbiter who is associated with eco-friendly product development, location where it is being managed and conductor; each role fills out according to the important incident. This is connected with scope of investment to draw out what eco-friendly design methodology could have as the most ideal market impact and scenario that could happen in long-termed and short-termed investment. Lastly, each is applied onto visual tool and comparative analysis tool to draw out separate impact on environmental and in business (chapter 9).

Chapter 9 will show that the business chain will be the guideline for analysing the business perspective, illustrating the relationship between decision makers and various influences. To establish the background data, it will undertake expert interviews in chapter 8 and it will illustrate the relationship between environmental effectiveness and the size of investments through these. Consequently, these results will show appropriateness rating for eco design methods, related to departments and contexts of product development.

Phase B3 will show the results regarding the estimation for maximum size of investments, which will maximise business results considering current and future market conditions against changing eco scoring.

1.9 Summary

To improve values for environmentally friendly design cannot ignore economic benefit and various market requirements. Although since the development of environmentally friendly design concepts, various designers and historical attempts have continuously been undertaken however, there are not many valuable design

results compared to other design areas such as functional or aesthetic design approaches. That means if the product design does not reflect the consumer demands, which ignores fundamental and essential design principles, then the product lifespan can be shorter and increase environmental demands with serious environmental effects and growing social concerns. Hence, the concept of environmentally friendly design, which this research reviews, should follow industrial design principles and reflect consumer demands (Edwin Datschefski, 2000).

To implement these research aims, the researcher will explore eco design methods and establish applying this framework to the design object and analyse the design results by quantitative methods (however in this research LCA will use as qualitative approach –more information in chapter 3 and 5). To find the current limitation of eco design implementation and the potential business possibilities of eco product development in the mobile phone company, the author has undertaken various interviews with Korean mobile phone manufacturers. After the implementation of these processes, exploring and denoting the ranking of appropriateness for the eco design methods, the author will match the effectiveness of eco design methods with different influences and decision makers.

In conclusion, the results through these approaches will highlight the various difficulties, which have been faced in undertaking business and these findings will provide guidelines to select eco design methods for undertaking eco design methods within manufacturers.

Chapter 2. Understanding environmental aspects

Precis of chapter 2

- To determine the major international environmental regulations, which have influenced the electronic and electric industries
- To find what contents of international environmental regulations currently impacting on the electronic industry field and finding core context from each these regulations
- To determine difficulties of implementing recycling activities against growing up the market values
- To deduct validities research target via the background researches about statues of Korean mobile phone industries

This chapter will show the validity of research objectives that have been adopted to find the effectiveness of differing eco design methods. This also presents various international eco regulations, which trigger significant opportunity to open the Green round era. The mobile phone industry is applied as the research object, which has recently rapidly expanded the size of markets globally (section 2.3), above any other electric and electronic product group. Korea has several key mobile phone manufacturers and service providers (section 2.5). Korea's economic system is dependent on foreign markets for trade (section 2.4) therefore various international environmental regulations have directly influenced Korean industries. International environmental regulations have had stronger content since the Millennium; for instance major eco restrictions such as the Kyoto protocol, WEEE, RoHS and EuP which have specific areas where these issues have worked at becoming the new trade wall (Green Round).

An environmental friendly design can be a method to make a dramatic change in industrial design. Therefore in this research, I will deal with a method to apply the environmental friendly design in business practice of the industrial design.

2.1 International eco regulations in the electronic industry

General analysis of various factors on electronic products; Global environmental impacts through electronic products

The United Nations Conference on the Human Environment (1972), International Union for Conservation of Nature (1980) and Rio Declaration on Environment and Development (1992) established an atmosphere that international organisations need to consider the environment to achieve sustainability. These efforts have stimulated the international environmental regulations, which have legal force and segmented areas these significantly put pressures on the companies' environmentally and sustainability or eco-friendly factors which have become key issues in product developments since then (Korean Ministry of Knowledge and economics, 2010).

- International environmental regulations

The Green round was after the Uruguay round is a multilateral trade negotiation and has been started by creating various International environmental regulations, particularly since taking the effect of the Restriction of Hazardous Substances (RoHS) and the Waste Electrical and Electronic Equipment (WEEE). These regulations have directly impacted industries especially the electronic products and car manufacturing (Korean Ministry of Knowledge and economics, 2010).

Name of major international eco regulations	Activation date	Area of effect
Waste Electrical and Electronic Equipment (WEEE)	2008	Electronic product/ Automobile
Restriction of Hazardous Substances (RoHS)	2003	Electronic product/ Automobile
European Union's End-of-Life-Vehicle Direction (ELV)	2000	Automobile
EURO II / III / IV	II: '96.1.1 III: '00.1.1 IV: '05.1.1	Automobile
Local exhaust ventilation (LEV)	Tier II:'04	Automobile
Integrated Product Policy (IPP)	2001	All industries
Registration Evaluation Authorization and Restriction of Chemicals (REACH)	2007	All industries

Table 2.1 Major effective international regulations since 2000

These various international environmental regulations have had more powers, have been centred on the EU and many advanced countries have led and created new policies based on Agenda 21 (1992) and the Kyoto protocol (2005), which directly impact the economy.

In 2008, these regulations were extended to become new trade-barriers for the advanced countries such as the EU, US and Japan for example, energy using Products (EuP, 2008). If the products, which use energy (except automobiles) want to sell in the EU, they have to consider the environment (need to apply eco design) and according to Samsung environmental research LAB “EuP provided the turning point from recommendation to obligation” (Money Today, 21. 11. 2012).

These international efforts and regulations have created the concept of ‘Sustainable development’ and this has influenced companies’ business management and design management.

2.1.1 Significant environmental policies in different areas (EU / US / Japan)

2.1.1.1 Environmental policies in EU

EU environmental policies have very powerful restricting factors and segmented structures compared to other countries and markets policies, for instance most EU markets should have followed the fundamental guideline of the Strategic Environmental Assessment (SEA) (2003) and Environmental Assessment (EA) (1988) (Social and cultural analysis of environmental perspective, Korean Ministry of Knowledge and economics, 2010).

The EU environmental policies and regulations have influenced other countries’ policies, for example, when the health care factors were included to Espoo Convention (1991) by the United Nation Economic Commission for Europe (UNECE) and SEA, these had become to standard in EA system (Hun Gu Yeo, 1996).

Item	Obligation rate
Lager size home appliance and bending machine	Recycling material rate in one product - minimum over 80% per average weight Recycling and Reusing rate of raw materials in total components - minimum over 75% per average weight
Small size home appliance, light, electric and electronic tool, sport equipment, toy	Recycling material rate in one product - minimum over 70% per average weight Recycling and Reusing rate of raw materials in total components - minimum over 50% per average weight
IT device, communication device, consume goods	Recycling material rate in one product - minimum over 75% per average weight Recycling and Reusing rate of raw materials in total components - minimum over 65% per average weight
Gas lamp	Recycling and Reusing rate of raw materials in total components - minimum over 80% per average weight

Table 2.2 Contexts of the Strategic Environmental Assessment (SEA) (2003)

Consequently, the purpose for environmental policies in the EU are; i) the preservation of European nature, ii) increasing social awareness and marketability of eco products and iii) protecting trade by environmental regulations.

These major environmental policies and regulations have been in force since 2003 affecting the electronic product markets and economies particularly globally.

- Integrated Product Policy: IPP (2003)

This policy provided significant guidelines to undertake a sustainable development strategy in the EU with the key issue being, manufacturers and providers have to consider various methods to improve environmental effects within the entire product lifespan.

IPP considers product development costs, product quality against outside environmental effects to find better environmentally friendly products within economic constraints and also encourage verified design and manufacturing within companies. The purpose of the policy is to extend the green markets and consumers globally whilst reinforcing the manufacturers' and providers' environmental responsibilities.

General environmental policies focused on usage levels (reducing waste and energy saving) are more considered and impact early stage product lifespan such as the design and planning functions.

- Energy using Products directive : EuP (2007)

Annually, one hundred thousands products, using electrical power (except automobiles), follow the EuP guide in production and if the product fulfilled the standard then it can attain the CE Mark (The CE mark is an abbreviation of French, Conformité Européenne and means European Conformity).

This segmented product lifecycle has six stages, that first stage is selecting and applying materials, the second stage is manufacturing, the third is packaging, delivering and shipping, the fourth is installation and maintaining, the fifth stage is using and the sixth stage is disposal.

This regulation has several environmental conditions;

- Amount of potential consumption in raw materials, energy and water
- Amount of air, water and soil waste emissions
- Amount of physical waste (noise, tremor, radioactivity and electromagnetic wave)
- Considering rates of recycling, reusing and collecting energy through applied WEEE standards

Since 2003 EuP has become an essential factor for global manufacturers who want to enter the EU markets and also the regulation demonstrated a new wave of manufacturers' responsibilities, where electronic products need to show the ecological parameters, such as material composition and process.

- Waste Electrical and Electronic Equipment (WEEE)

This regulation enacted a duty of collecting waste for the retailers and manufacturers, who sell or produce the product since 2007 and the companies who follow this regulation are only able to sell in the EU area (Social and cultural analysis of environmental perspective, Korean Ministry of Knowledge and economics, 2010).

The regulation made a new paradigm that the main subject of recycling and reusing was from consumers to providers and means namely, WEEE emphasised and highlighted the manufacturers and retailers' responsibilities.

Product group	Items
Large size home appliance	large size cooler and refrigerator, freezer, clothes dryer, dish washer, cooking equipment, electric heater, microwave, electric radiator, electric pan, air conditioner
Small size home appliance	Vacuum cleaner, iron, toaster, electric knife, hair dryer, electric toothbrush, watch, scale
IT / Communication Device	Data processor, printer, PC related facilities (CPU, mouse, screen, keyboard), photocopier, laptop, notepad computer, fax, phone(public phone, wireless phone), mobile phone
Consumer electronics	radio, TV set, video camera, video recorder, audio amplifier, instrument
Light	fluorescent light, high pressure sodium vapor lamp
Electric / electronic tool (except industrial tool)	Electric drill, electric saw, sewing machine, punching system, soldering and welding tools, electrical lawnmowers
Toy/leisure/sport equipment	Video game, electrical sport equipment, slot machine
Detectors and controllers	Smoke detector, heating controller, thermometer
Banding machine	Cool / hot can bending machine, ATM

Table 2.3 Major product item lists of WEEE (Korean Ministry of Knowledge and economics, 2010)

These facts are provided by WEEE, involve a wide range of electric and electronic products in all product categories and follow contexts below.

- i) Waste electric products are controlled by WEEE and regulated using under AC 1,000V / DC 1,500V electricity.
- ii) The member countries have to establish a collection system for home appliances and non-household electric products since August 2005.
- iii) The member countries have to make a recycling obligation rate with product categories and the company who produce, sell and distributes in the EU have to follow this rate from January 2007.
- iv) The manufacturer are burdened with expenses for building collection systems for the products that are produced after 13th August 2005, however with products

produced before that date, the manufacturers who work in the same markets share costs.

v) The manufacturers have to evaluate the components that require specialist treatment, ie: PCB condensers, refrigerant materials (CFCs, HCFCs, HFCs, HC), gas lamp, external electric wire, printer toner, BFRs: Brominated Flame Retardants and Radioactive material- by 75/442/EEC regulation before undertaking the reuse, recycling and reclaiming processes.

Item	Reclaim rate	Reuse / Recycling rate
Large size home appliance / bending machine	80%	75%
IT device / consumer electronics	75%	65%
Small size home appliance / light / electric tools / toy / leisure equipment / sport equipment	70%	50%

- The standard of rate is estimated by weight of components and materials from collected products

- Meaning of reclaim: using thermal energy

- Meaning of reusing: using it to the same purpose

- Meaning of recycling: using the waste in many ways except collecting energy

Table 2.4 The obligation rate of EU recycling from 2007 (Korean Ministry of Knowledge and economics, 2010)

- Restriction of Hazardous Substances (RoHS Directive)

RoHS is an initial attempt to limit the use of toxic material with decreased recycling opportunities leading to environmental pollutants during the disposal and recycling processes. Since January 2006, this regulation has controlled six major toxic materials used in electrical products in the EU market.

i) It has eight target product groups, which are the same targets as WEEE (large size appliance, small size appliance, IT communication equipment, consumer products, light, electric tools, toy/leisure/sport equipment and vending machines).

ii) The restricted materials are Lead, Mercury, Cadmium, Hexavalent chrome, PBBs and PBDEs.

iii) This regulation has exception rules for small amounts of mercury in fluorescent lamps, Lead in glass for electric components and batteries only follow battery regulations, therefore the standard of mobile phone batteries follows battery regulations.

In the Green round era (after the Uruguay round), WEEE, RoHS and the Kyoto protocol have greatly influenced Korean electronics markets because Korean major trading countries such as China, US, Japan and the EU are members of these regulations so to undertake economic activities continuously, Korean manufacturers comply with international environmental regulations effectively. Especially WEEE and RoHS, which provided chance to change who has the environmental responsibility from consumers to providers. These regulations contained compulsory sanctions comparing traditional environmental standards giving various impacts to the national economy and society. Moreover, these restrictions also worked as the filter that verified whether they effectively dealt with the new environmental restrictions or not for companies and nations in the green era where they led to bigger gaps between advanced companies who have environmentally advanced technologies, systems and followers.

2.1.1.2 Environmental policies in the US

Current US national environmental regulations are based on National Environmental Policy Act (NEPA) and were developed in 1970. This legislation contains an evaluation of the environmental impacts and this analyses contents of individual projects as well as policy, planning and programs related to projects. However environmental evaluations have been undertaken through self-decision to generate better ideas in decision making processes in product development therefore attaining EIS: the Environmental Impact Statement which is not an essential process to proceed the project.

US environmental policies can be divided into federal and local governments.

US federal government follows NEPA principle and CEQ (Council on Environment Quality), which is a direct institution of the US president. CEQ uses sub strategies and guidelines for implementing NEPA regulations and CEQ guidelines control the entire local government environmental policy. Moreover, when dealing with EU and Asian markets, they have stronger environmental legislation; CEQ published environmental scoping guidance and is currently preparing new environmental restrictions with a legal requirement.

The environmental policy in local government follows NEPA and CEQ regulations and guidelines are based on this environmental legislation and 17 States and Cities are preparing their own environmental guidelines for implementing EIA (Environmental Impacts Assessment).

Despite this the US has created various historically successful environmental achievements (e.g. Earth day, 1972) and various NGOs are environmental activists, however developing environmental restrictions, which have strong legislation such as the EU environmental policy, RoHS and WEEE which are directly related to industries have not accomplished success yet compared to other industrially advanced countries. Moreover, compared with the EU environmental legislation, US NEPA and CEQ guidelines were not implemented for the management of industrial waste or control of their recycling systems and standards for energy consumption was more tolerant compared to other countries.

However, CPSC (Consumer product Safety Commission) established the CPSIA (Consumer Product Safety Improvement Act) regulation and found lead from metal toys and 1.5 million toys were recalled in 2007 and restrictions using lead, Phthalate and flame resistant materials can appear harsh environmental restrictions.

2.1.1.3 Environmental policies in Japan

Japanese environmental efforts started early as opposed to other current environmentally advanced countries because historically, serious environmental social issues occurred such as Itai-itai disease (1960) and Minamata (1932). Therefore Japan established 'the strategy of environmental preservation centred on public businesses in 1972. After the creation of initial legislation, Japan developed 'Evaluation guidelines for environmental impacts' and the 'Law of public water surface' and also developed individual phases for environmental protection in 'legislation of local government'. In 1997, the Japanese cabinet established the 'law of evaluation environmental impacts': Japan is the only country that evaluates environmental impact at a national legal level.

At Japan's environmental planning in 2006, the Japanese government recognised environmental issues have to reflect industry, therefore it provided SEA (Strategic Environmental Assessment) for undertaking environmental evaluations more strategically.

According to the '21st century Environmental nation', established in 2007, the Japanese government announced three strategies: 'Building a low carbon society' which aims at sharply decreasing amounts of greenhouse gas emissions and soil consumption reduction, 'Building recyclable society' aims to develop a sustainable society through increasing rates of recyclable resource and waste reduction and 'Building an ecological co-existence society' promoting opportunities to bring harmony between man and the environment.

2.2 International eco regulations impacted on the mobile phone industry

Current mobile phone industries have impacted mostly on major international environmental regulations such as WEEE, RoHS, Kyoto protocol and EuP and furthermore, depending on the markets, more legislations have also controlled e.g. UK market requires EEE (Electrical and Electronic Equipment), Eco design Directive and the Producer Responsibility Obligations Regulations 2007. These international

and local environmental legislation can be distinguished with traditional environmental restrictions by having the very clear and narrow boundary and standards and these recent legislation has worked as new trade walls (see Green Round in chapter 3). Therefore manufacturers and product service providers have to fulfil these standards to import or export and moreover, the modern environmental legislation requires providers' to be responsible rather than consumers'. A consequence of the environmental issues faced in entering the new paradigm is that they have merged with economic values to become a globally competitive area.

2.3 Current circumstance about mobile phone recycling

This section will show the material compositions in a mobile phone and will also find environmental impacts compared to PCs.

A mobile phone is the personal electronic products and only generates very small amounts of environmental impact rather than normal electronic handheld products (SA report, 2013). However, the size of the mobile phone sector and users have explosively expanded and the features for Korean mobile phone users, which is the target of this research have i) one of the fastest mobile phone renewal frequencies and ii) have top level global manufacturers (SA report, 2013). Moreover, as mobile phone have become slimmer and more compact, various toxic materials have been used; antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn), which persist and bio-accumulate in the environment. In particular, Pb (a suspected carcinogen) has adverse effects on the central nervous system, immune system and kidneys, and it has been linked to developmental abnormalities. Therefore the EU established RoHS in 2006 to restrict using these harmful materials (especially RoHS which is more focused on eradicating lead (Pb) use) and currently through RoHS and WEEE, international organisations and national governments, who follow these regulations have controlled many toxic materials in particular industries.

Contents	1999 Mobile phone (~0.08Kg) (% of Total Weight)	1999 PC with Desktop (~26Kg) (% of Total Weight)
Plastic	46	23
Lead (Pb)	0.9	7
Aluminum (Al)	9	14
Iron (Fe)	8	21
Tin (Sn)	1	1
Copper (Cu)	19	7
Nickel (Ni)	1	0.8
Zinc (Zn)	3	2.2
Silver (Ag)	0.9	0.02
Silica (Si)	4	25
Mercury (Hg)	1	0.01

Table 2.5 Material composition comparison between mobile phones and desktop personal computer (Nokia SVTC 1999 Plastic contains poly-brominated flame retardants and hundreds of additives and stabilisers) (SA report, 2013, Stern review, 2013)

The estimated volume of mobile phone waste per year (100-200 million) in the US and this data approximately 1.5 years down from 3 years in 1995 was based on Fishbein who previously estimated mobile phone waste could exceed 500 million by the end of 2005, could generate up to 198,500 Kg of Pb, and currently these estimations have realized (Stern review, 2013).

Table 2.5 also shows the material compositions of mobile phone and personal computer. As this figure shows mobile phone used 46% of plastic in rates of total weight and this result outweighs the phone plastic rate compared to personal computer (23%). Confidently, the mobile phone was made before 2006 used Pb (0.9%) and Mercury (1%) however this figure is centred on 1999, which is RoHS enforcement by Nokia therefore currently using Pb is wholly restricted. Brominated flame-retardants are used in almost all electronic equipment included mobile phones and computers using the radiant of fire materials however was found to contain carcinogenic. The meaning of this figure rate for use of toxic materials for individual mobile phones was not higher whereas considering volume and total weight of producing the waste (see table 2.6) the mobile phone industry could be a significant environmental polluter (SA report, 2013).

Products	Total disposed	Trashed	Recycled	Recycling Rate
	Tons	Tons	Tons	%
Computers	423,000	255,000	168,000	40%
Monitors	595,000	401,000	194,000	33%
Hard copy devices	290,000	193,000	97,000	33%
Keyboards and Mice	67,800	61,400	6,460	10%
Television	1,040	864,000	181,000	17%
Mobile devices	19,500	17,200	2,240	11%
TV peripherals	Not included	Not included	Not included	Not included
Total (in tons)	2,440,000	1,790,000	649,000	27%

Table 2.6 E- waste by the ton in 2010 - was it trashed or recycled (According to the EPA, 2012)

According to EPA (Environmental Protection Agency) report about e-waste announced (2012), 142,000 computers and over 416,000 mobile phones are wasted in the US every day. In 2011, the US generated 3.41 million tons of e-waste and only 850,000 tons; 24.9% was recycled (EPA 2011). This figure was calculated on weight, although mobile phones were only one twentieth of an entire computer or monitor, however it can be estimated that mobile phones have had a significant environmental impact by considering the rates of increasing volumes of consumers versus such a low rate of recycling. Figure 2.1 demonstrates amounts of disposed electronic product and amounts of recycling product in the US in 2010, and despite the enforced WEEE and RoHS, which have widely influenced electronic industries and markets, the rate of mobile phone recycling only achieved 11%, which was only one quarter of computer (40%) recycling rates.

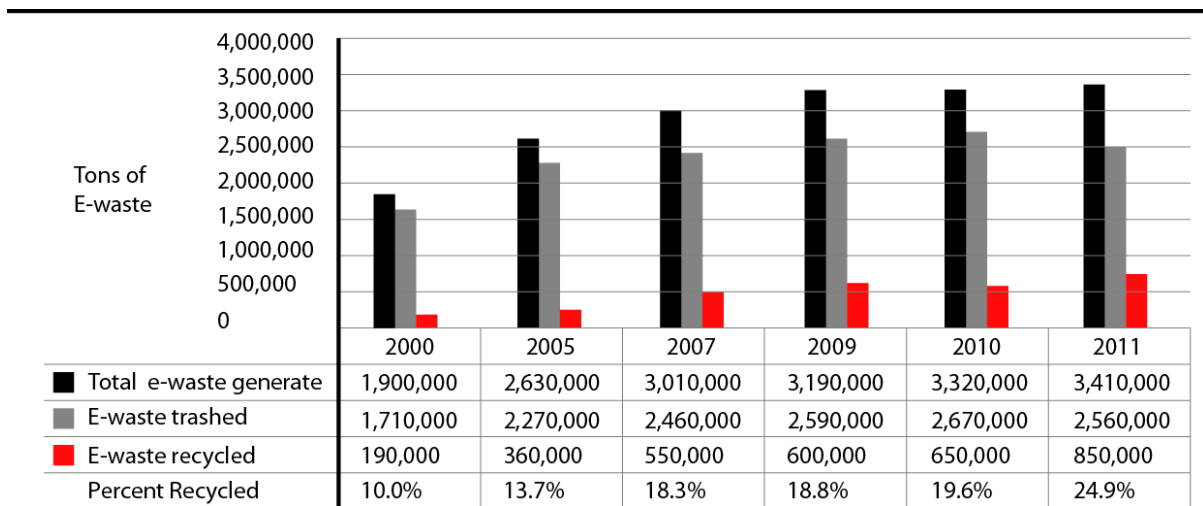


Figure 2.1 EPA data from 'Municipal Solid Waste in the United States, 2011 Fact and Figures' 2013

Figure 2.1 shows the amount of US solid waste, where total amounts of solid waste in 2011 increased approximately twice more than in 2000. The major reason for this fact can be assumed by increasing the use of electronic products however although rate of recycling percentage have increased from 10% to 24.9% but this result was only a small sample. Moreover in 2005, the recycling rate had rapidly increased and the reason at that time was that it was the first year of enforcing WEEE and RoHS, which currently influence recycling and waste management.

The EPA reported 20 to 50 million metric tons of E-waste disposed every year and most of this waste contained toxic materials such as lead, cadmium, mercury and other hazardous waste and furthermore these materials have become secondary pollutants by becoming obsolete. In 2004, 183 million computers were purchased and these products still contained these harmful materials.

	Global sales				
	Amount of purchased in 2010	Amount of purchased in 2011	Amount of purchased in 2012	Amount of will purchase in 2013	Future year projection
Computer					
Computer; PC, Desktop	350.9 million (Gartner)	352.8 million (Gartner)	341 million (Gartner)	Over 305 million (Gartner)	271 million PCs in 2017 (Gartner)
Tablet PC	19.5 million (Gartner)	72.7 million (E-reader source)	103.4 million (Gartner)	240 million (Gartner)	467 million in 2017 (Gartner)
Ultra book, Ultrathin PC tablet			9.8 million (Gartner)	20.3 million (Gartner)	96 million in 2017 (Gartner)
Servers	8.9 million (Gartner)	9.5 million (Gartner)			
Television					
All television	247 million (Gartner)	255 million (iSuppli)	238 million (iSuppli)		253.1 million in 2015 (iSuppli)
Smart TV (Only connected)			66 million (iSuppli)		141 million in 2015 (iSupply)
Mobile phone					
All mobile phone	1.211 billion (Gartner)	1.59 billion (Gartner)	1.75 billion (Gartner)	1.82 billion (Gartner)	1.9 billion in 2014 (Gartner)
Smart phone	304 million (IDC)	491.4 million (IDC)			Over one billion in 2015 (IDC)

Table 2.7 Amount of Global electronic products sales, 2011 Fact and Figures' 2013 (CEA 2011)

Table 2.7 shows the amount of global electronic products (computers, televisions and mobile phones) from 2010 to 2013. This figure used several market research reports from Gartner, iSuppli, IDC and E-reader source. According to this figure, the amount of global mobile phone users will have reached over 1.2 billion and in 2014, the entire mobile phone users included smart phone will be around 2 billion. This fact means that in 2013 total amounts of global mobile phone users will be reached 40% of the population (according to World Population Clock centred on 8 billion, 2013 the world population reached 7.1billion) and furthermore as the quality of life in developing countries increases, particularly in China and India, which have the highest levels of population, populations will obviously increase.

In addition, shifting the social and market trends, where current consumers have had more dependence on mobile communication devices and smart technology e.g.

tablet PC and smart phones are convenient and have higher motility rather than traditional computers such as desktop and PC markets influence this result.

For example, common usage of personal PCs at home can make people's life more efficient and fast, but this rapid increase in personal PCs including smart phones can have a negative impact on the environment (EPA, 2013).

In summary, users of mobile phones and mobile communication devices have been continuously increasing however, this market growth can be connected by producing increased E-waste, and therefore international environmental regulations will be more segmented and environmental requirements from markets will become more diverse as markets expand.

Consequently, as more stringent and concise international environment standards are developed, various environmental requirements will be decide for manufacturers survival through production restrictions, sales and distribution e.g. WEEE and RoHS changed the electronic market and industries structures and systems. In contrast, these new legislations could bring new opportunities, can provide direct and indirect advantages to forward looking new providers, who have effective and identifiable environmental strategies and technologies.

2.4 Korean eco regulations in the electronics industry

In May 2005, the Korean government announced a 'Vision of Presidential Commission on Sustainable Development' to stimulate and establish environmentally friendly economic structures by implementing a positive national environmental policy. This national vision provided various ecological opportunities; i) to achieve balance between IT and ET (environmental technology), government and industries will undertake cooperate projects and ii) to enter the advanced environmental global markets, government incubates SMEs who have the potential opportunities through innovative environmental technologies (KOTRA, Green Inno-Biz and investment, 9, 2009). In September 2008, the Korean Ministry of Knowledge and Economy announced a 'Vision of new growth and developing strategy' and this

has six categories based on the 'Knowledge base economy', 'Convergence of new technologies' and 'Building innovative green business models for effectively dealing with energy and the environmental crisis' are twenty two new opportunities.

These developing strategies are not only focused on developing technologies but also consider convergence of high technologies with environmental social issues and establishing levelling the system of achievements that are based on relationships between technology achievement and market share. To achieve 'Green IT strategy' governments established 'Green of IT' and 'Green by IT' strategies. 'Green of IT' is focused on ecological development to computers, TVs, displays and servers and also has three major IT products; Internet equipment, semiconductor and network products.

Through this strategy it achieved ten times faster Internet technology and also high efficiency energy consumption in 2012. In particular rapid growth in the semiconductor and IT industries by a boom in mobile phones and display industries, Korean large companies such as Samsung and LG electronics became global companies and as such their success led to foreign investment. Hence, to continue these positive markets conditions, Korean manufacturers have been required to invest in building environmental facilities and developing eco products. For instance J.P Morgan, which is the world's biggest asset management company invested 1 billion US dollars into green technology development and the green fund in Korea, 2008.

The size of the global IT market in 2012, despite of global financial difficulty, achieved 500 billion US dollars and ITC estimated the market will rapidly increase to around 4.8 billion US dollars in 2013. The Korean IT industry has also increased their global market, however the Korean market developed as the environmental issues were more economically biased, they built high performance IT infrastructures, possessed various world class IT manufacturers and service providers and supported the Korean government environmental project called 'Green IT national strategy'. The Korean government invested in the development of eco technologies for applying to particular displays, digital TVs, mobile phones and IT equipment. The "Green IT national strategy" developed IT convergence products to be more

ecological, the Korean government has implemented this since 2010 and accomplished effective convergence; it led to the green industry and helped to build environmental infrastructure.

The definition of this national strategy is ‘Making a green economy to lead the Economic Quality Growth to accomplish sustainable development and achieve green growth by Eco-Efficiency through undertaking Social Responsibility’.

The purpose of these are that i) the government supports the IT industry continuously by promoting convergence with environmental issues, ii) finding new IT markets have been saturated globally, iii) require various internal and external pressures such as international regulations and markets demand and iv) needs to build Korean style green products where the IT industry has become the major industry in the Korean economic system.

6 categories	22 new opportunities
Energy / Environment	Chemical free coal energy, marine bio energy, solar battery, collecting CO2 and recycling enterprise, energy generate system, nuclear power plant
Transportation system	green car, ship making and marine system
NEW IT technology	Semiconductor, display, next generation wireless communicator, LED light, RFID/ USN
Convergence / Inno-Biz	Robot, developing new material and Nano-convergence, IT convergence system, New media equipment by Broadcasting-communication convergence
Bio	Bio medicine, Medical equipment
Knowledge base service business	Software, design, Healthcare, cultural contents

Table 2.8 Green IT national strategy (Social and cultural analysis of environmental perspectives, Korean Ministry of Knowledge and economics, 2010)

Korean eco markets recently adopted EuP (Eco-design requirement for Energy-using product) method which leads to ecological planning and entire Korean industries have had consensus that environmental problems will be a crisis but there will be new opportunities hence, the industries and government are building long-term environmental roadmaps.

Table 2.9 shows the increasing rate of the Korean environmental budget and tax supported by the Korean Ministry of the environment (2006) which illustrate how important environmental issues in Korea are and demonstrated its rapidly rising

importance (2006' Korean white paper about the Environment, Ministry of Environment). The meaning of the environmental budget is centred on the Korean Ministry of the Environment with the Korean Ministry of knowledge and economy, which established annual budgets to achieve 'environmental improvement' in various ways.

Classification	2004		2005		2006		
	Budget	Actual result	Budget (A)	Actual result	Budge (C)	Plus and Minus	%
Total	704,367,222	762,112,222	1,393,854,444	1,452,385,000	1,462,548,888	68,694,444	4.9
Incoming itself	501,472,222	558,890,555	544,106,666	593,051,666	602,746,111	586,394,444	10.8
Environmental improvement share	315,160,000	291,513,888	334,911,111	316,736,666	351,733,333	16,822,222	5.0
Discharge Share	9,105,000	7,183,333	9,320,000	6,143,888	8,190,000	1,130,000	12.1
Waste deposit	82,222	533,333	71,666	917,777	97,777	26,111	36.4
Recycle share	2,777,222	2,283,333	3,073,333	1,962,777	2,504,444	568,888	18.5
Waste Share	20,896,666	19,561,666	20,375,000	24,933,333	27,159,444	6,784,444	33.3
Water quality improvement share	9,902,777	8,132,222	7,932,777	9,432,778	8,591,666	658,888	8.3
Eco system preservation share	7,158,333	19,238,333	8,951,666	20,489,444	19,573,888	10,622,222	118.7
Withdrawal loan	55,065,555	66,348,333	72,855,000	91,353,888	93,544,444	20,689,444	28.4
Money for trade	91,666	139,444	421,777	500,555	423,333	10,555	2.6
Etc	67,136,111	75,042,777	65,972,222	55,361,111	79,592,222	13,620,000	20.6
Bringing forward	14,071,666	68,913,888	20,231,111	9,688,888	11,335,555	8,895,555	44.0
General accounts	202,920,000	203,221,666	849,747,777	859,333,333	859,802,777	10,055,000	1.2

Table 2.9 Structure of the environmental budget (unit: GBP) (Statics of Korea, 2007)

The self-revenue consists of 7 generations share, which are The Environmental Improvement Share, The Discharge Share, The Waste Share, The deposited amount for the Waste, Recycling Share, The Water quality Improvement Share and The Ecological System preservation Cooperation and a loan recovery was increased to 4.9% in 2006. The amount of revenue of these 7 generations share 69.3% (7,521 thousand million won) of the entire amount in self-revenue and loan recovery positions, which account for 15.5% (1,684 thousand million won) in a whole self-revenue. The general account increased by 1.2% (1billion 5,476 thousand million won) from 2005. Between 2003 and 2004, the estimated cost for the water supply and drainage and cost for the construction a rubbish tip drastic cut however R and D budget for the atmosphere, which are supplying LPG gas vehicles, the next generation environmental technology R and D and environmentally improvement

technology were heavily boosted. In 2006, the Metropolitan area atmosphere improvement measure propelled, to over 10% of the budget estimated for the whole environmental improvement budget (2006 Korean white paper about the Environment, Ministry of Environment).

To implement the Low carbon and green growth policy, the Korean government's efforts to reduce soil energy consumption and pollution there are lists to support environmental tax, environmental pollution prevention facilities and LPG supplies facilities. For example, reviewing table 2.10, the Korean government spent about 40 million pounds in GBP (81,915 million won) to promote the use of LPG in 2005, however this tax support decreased in 2013.

A field of Support	A Scale of Support	A limit of Support and Percentage		A interest rate	A Period of loan	Repayment
Facilities for fire prevention	81,915 million won	Each field	Exceeding 50 hundred million won	Fluctuating interest	In 10 years	Every 3months
Construct agent		-				
Development technology		Cost for the development technology	Exceeding 3 hundred million won			
Industrialization cost		Cost for the Industrialization	Exceeding 10 hundred million won			

Table 2.10 Condition for environmental improvement fund (The whitepaper, the Korea Ministry of Environment, 2005)

Despite supporting various environmental tax policies in Korea, the electronic and electric industries have not had any examples that succeed in getting tax support because i) Korean eco policies in electric and electronic product categories only concentrated on percentage of recycling (to get the tax support the product has to use over 90% of recycled material and that is a higher standard than the EU standard; the EU standard uses 70%) therefore most Korean manufacturers could not achieve this standard. For example Samsung Blue earth phone, which was 70% of recycled pet bottles succeeded to get the eco label in EU but this model could not get any support from Korea. ii) Various Korean environmental organisations especially are focused on the electronic and electric industry but could not establish an eco-labelling system for public confidence yet and this situation had a significant negative influence.

Since the Millennium, environmental industry has become the core industry for sustainable improvement; a balance between the environment, economic and sophisticated technical style, which can be explained by the knowledge industry, providing equipment and longer-life service to restore contaminants (the Korea Ministry of Environment 2009).

Several international environmental regulations appeared, the connection of the environment and trade (economic benefit) has been implemented by environmental and social necessity hence, it stimulated increasing green produced product consumption and consumer's ecological awareness. The environmental markets have grown for up for 10 years steadily (4,741 hundred million in 1996, 5,320 hundred million in 2000 and 5,890 hundred million in 2004) and it is estimated at 3% growth standard from 2004 to 7,083 hundred million in 2010 (EBI, 2004).

According to a report from the Korean national Bank (2009), developing countries especially in East Asian countries recorded approximately 7% growth with sudden industrialisation and increasing national environmental demands furthermore, China has an environmental turning point at the Beijing Olympics 2008 and Shanghai Expo 2010 estimated from between 15 and 20% rapid growth. Such environmental demands also appeared in Korea. The Korean environmental market scale recorded 9.1% growth and this volume positioned 2.97% in 2005 of GNP (16 billion and 866 hundred million won in 2004 / 14 billion and 7,414 hundred won in 2003) (Korean national Bank, 2005). The Korean environmental market has grown over 10% in every year since 1998 (which occurred significant national financial crisis) and this growth continues until 2010 however the speed of market growth has slowly shifted to advanced country type market, which is more focused on the infrastructure system demands and based on consumer's ecological awareness (the Korea Ministry of Environment 2009). Consequently, according to 'the research on the environmental industry statistics centred 2004' from the National Statistical Office, Korea has got 23,036 environmental industries, which are 3,446 manufacturing factories (14.9%), 1,138 architectures (5.0%) and 18,452 services (80.1%). These environmental trends were based on the social trends that environmental benefit can relate to improve the quality of life; such as wellbeing. According to these facts, the Korean

government announced 'the Core Leading Industries for the Future' (2010) the ET (Environmental Technology) had 2nd ranking in the top 10. Furthermore, the Korean government also invested 1 billion won (60 million pounds GBP) every year since 2001 for undertaking environmental preservation project is called 'Eco-Topia 21' and hence, Korea is ranked 5th in the world's top countries for possessing environmentally high technology.

2.5 Why mobile phone industry?

This section will illustrate the appropriateness and validity of the chosen research subject and also provide general features on the perspective of global markets and the industrial situation of the mobile phone industry. Consequently through these sections the author will show the specific definitions and features that create possibilities and adaptability for eco design methods within this research.

2.5.1 Growth of the mobile phone industry

A mobile phone market achieved one of the fastest developments that has the largest volume of consumers and largest global markets within the entire electronic product market. There are several causes explaining this rapid increase. However, the most plausible explanation is that this development in technology satisfies people's needs and people can communicate more efficiently using such technology. (Hyun Joo Lee, 2014). In addition, the changes in the size of the family emphasize the need for an anonymity and privacy which adds importance of these personalized items (Jong Ki Kim, 2013).

Comparing initial mobile phone model (name and year) to refrigerator (developed initial model in 1834 (invented by Jacob Perkins) and TV (1897, invented by Braun), a mobile phone has overtaken these traditionally strong products through innovation and convergence with other technologies over 80 years (initial mobile phone was developed in 1983).

The major reasons for this may be from several important features that can be distinguished with other products. Firstly the usage time for mobile phones is much

longer than for other products. According to general interviews in this research (section 7.4.3.1.2) general users use mobile phones for 3 hours every day, heavier user groups were 5 hours on average -. Therefore the people who are using mobile phone have more concerns and through this situation, the mobile phone can instantly reflect user perspectives and market reactions. There is a difference between heavy mobile phone users and light mobile phone users in time and the types of technology they prefer. People who use mobile phones often would like to sympathize with other people's life and wanted an immediate response from them. People in this category used other function in the phones. Also, they tended to display their superiority by using certain types of phones. This type of behavior was shown typically among teenagers. More information can be found in chapter 7 of this research. Among the heavy users, they put a lot of importance on the duration of the battery, and the time taken to download. On the other hand, for light users, they put an emphasis on the price and life-span of the item.

According to the Gartner report 2012, in total, 1.75 billion units (2012) of global mobile phones were sold to end users which was a 1.7% decline from 2011 sales figures, which included smartphones which helped to increase overall mobile phone sales, and the fourth quarter of 2012 recorded smartphone sales of 207.7 million units, up 38.3% from the same period in 2011 (Billion Mobile Phone Subscribers Worldwide By MOCOM2020 Team 4, 2009).

In 2012, 60% of the world's citizens have access to mobile phones (UN report 2012). The report showed the different functions of mobile phones when using mobile phones in poor countries, which could be significant equipment to improve their economy. As this graph shows, in 2009 the amount of mobile phone users was 3.5 times more than fixed line phone users. This accelerated when the smart phone was developed which also created a new mobile phone paradigm that use mobile phones not only for communication but for other functions such as pc device capabilities.

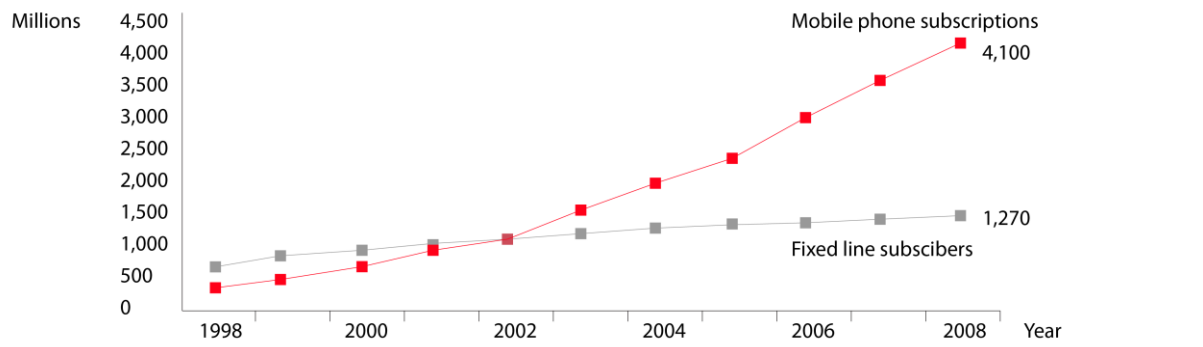


Figure 2.2 Increased mobile phone subscriptions (IDC, 2009)

As this table shows, global mobile phone users recorded were under 5 hundreds million people in 1998 however 10 years later in 2008, the global users increased to 4.5 billion people. This astronomical helped accelerate the development of the smart phone. In 2013, mobile phone have become a leading product, which reflects new technologies and consumer demands and historically it has strong marketing and design factors for appealing directly to consumers. The mobile phone can provide a variety of experiences to consumers rather than general electronic products, which have limited usage places, time and function.

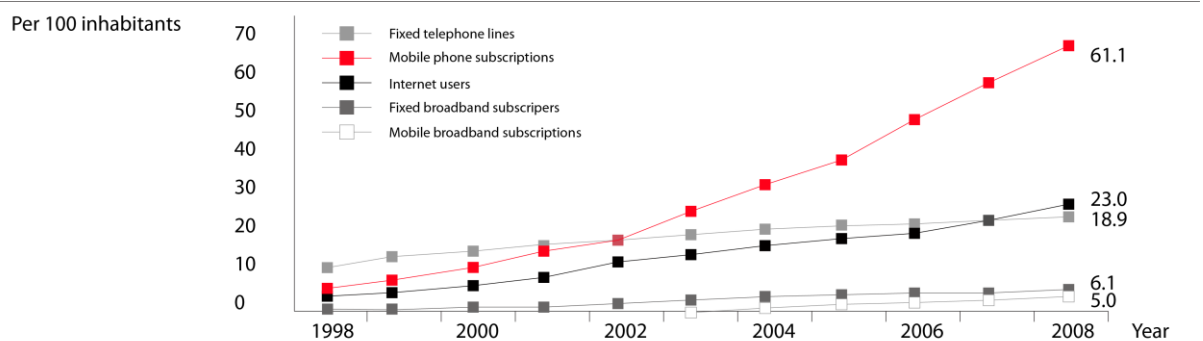


Figure 2.3 Analysis of mobile phone inhabitants compared to other communication devices (IDC, 2009)

Overall the magnitude of the global digital divide remains unchanged between 2002 and 2007. Despite significant improvements in the developing world, the gap between the ICT (Information Communication Technology) haves and have-not remains. When dividing the world into four groups of countries based on different ICT levels, a slight decrease in the digital divide can be observed between countries in the 'high' ICT group and those in the other groups. This could be due to an increase

in mobile cellular penetration levels in many countries that are part of the lower ICT groups. On the other hand, results also show that the digital divide between countries with 'upper' and those with 'medium' and 'low' ICT levels is increasing slightly. This suggests that as information societies become more mature, ICT levels flatten out. Less mature, but reasonably advanced information societies grow strongly, thereby leaving behind those at the lower end of the scale.

The Report also presents the latest 2008 figures for key ICT indicators. There has been a clear shift from fixed to mobile cellular telephony and by the end of 2008, there were over three times more mobile cellular subscriptions than fixed telephone lines globally. Two thirds of those are now in the developing world compared with less than half in 2002.

According to the IDC (International Data Corporation, US Research firm) reported estimation on worldwide mobile phone sales for the second quarter of 2013. In this table, Samsung has taken first place in the second quarter of market share in 2012 and 2013 and increased by 43.9% year on year, however compared to 52.3% growth for the entire market, the growth speed of Samsung and Apple (20.0%) have been slowing. although LG, Lenovo and ZTE, manufacturers failed to hit the 6% mark during the quarter whereas LG and Lenovo have achieved over 100% in year-over-year growth previously.

Vendor	2012 Unit Shipment (Second quarter)	2012 Market Share (Second quarter)	2013 Unit Shipment (Second quarter)	2013 Market Share (Second quarter)	Year-over-Year change
Samsung	50.3	32.2%	72.4	30.4%	43.9%
Apple	26.0	16.6%	31.2	13.1%	20.0%
LG	5.8	3.7%	12.1	5.1%	108.6%
Lenovo	4.9	3.1%	11.3	4.7%	130.6%
ZTE	6.4	4.1%	10.1	4.2%	57.8%
Others	62.8	40.2%	100.8	42.4%	60.5%
Total	156.2	100.0%	237.9	100.0%	52.3%

Table 2.11 Worldwide Smartphone Shipments in second quarter 2013 in Millions of Units (Source: IDC)

Although the smart phones have not been recorded in this research, this section shows how Korean mobile phone manufacturers influence global mobile phone markets. In the case of smart phones which impact significantly on current

international environmental regulations, particularly electronic restrictions such as RoHS, WEEE, Kyoto protocol and EuP hence, various mobile phone manufacturers have been developing environmentally high technologies to reduce waste and emission toxicities and to increase energy efficiency.

Vendor	2012 Unit Shipment (Second quarter)	2012 Market Share (Second quarter)	2013 Unit Shipment (Second quarter)	2013 Market Share (Second quarter)	Year-over-Year change
Samsung	97.5	23.9%	113.4	26.2%	16.3%
Nokia	83.7	20.5%	61.1	14.1%	-27.0%
Apple	26.0	6.4%	31.2	7.2%	20.0%
LG	13.1	3.2%	16.2	3.7%	23.7%
ZTE	15.2	3.7%	15.0	3.5%	-1.1%
Others	172.2	42.2%	195.2	45.2%	13.4%
Total	407.7	100.0%	432.1	100.0%	6.0%

Table 2.12 Worldwide Mobile Phone Shipments in second quarter 2013 in Millions of Units (Source: IDC)

In this table, the mobile phone market share in the second quarter of 2012 and 2013, Samsung were ranked 1st place and Nokia followed however Nokia marked -27.0% growth in year-over-year and long-running difficulties of selling smart phone accelerated their regular markets badly. According to the IDC report (2013), major users were the young generation (between 15-30 years old) more prefer digital devices such as smart phones whereas the older generation (between 50-60 years old) still worry about learning new devices therefore the IDC estimated Samsung, who produced smart phones and 2G (second generation phone) phones; both have more regular consumers than Apple, who only manufactures smart phones. In conclusion, major Korean mobile phone manufacturers, particularly Samsung and LG have given huge impact to the global markets especially Samsung who were first place in smart phones and mobile phone market shares in 2012 and 2013 and LG also recorded 108.6% growth in smart phone market share in 2013. According to these results, shows the appropriateness of selecting the Korean mobile phone industry research also illustrates how the Korean mobile phone industry impacts world mobile phone markets.

In summary, according to Gartner (2007), the world penetration rate of mobile phones has changed from 15.7% in 2001 to 49.6% in 2007 and the amount of world mobile phone subscribers recorded 33.1 hundred million means half of the world

population use mobile phones. As the increasing rate of users, which recorded 22.9% average increase usage rates between 2001 and 2007 and regionally, the Asia Pacific increased the most (15 hundreds million new users), Europe (8.9 hundreds million), America (6.5 hundreds million) and Africa (2.7 hundreds million). This rapid increasing industry and market could be the fastest paced in single product group history and recently the mobile phone industry is not only used for communication equipment but also these products lead world design, technology and moreover social trends. Hence, developing mobile phones through environmental approaches can heavily influence other industries and societies and can change the shape of electronic market structures.

Figure 2.4 shows the gap for mobile phone usage between advanced and developing countries. In this figure, in 2009, the average percentage of mobile phone user globally recorded 68.2% and advanced countries further marked 115.3%, which is 47.1% more and developing countries recorded 57.9%, is 10.3% less than average and 57.4% of gap between advance and developing countries. This gap can example the 'communication gap' (Castells, 2004) and that means as developing IT (Information Technology) or ICT (Information Communication Technology), the gap between countries will be more serious and make 'information rich' and the 'information poor', namely, levels of educational, income and type of occupation can influence different levels of communication importance and this communication gap will be more significant to global unbalance through the appearance of innovative new communication devices.

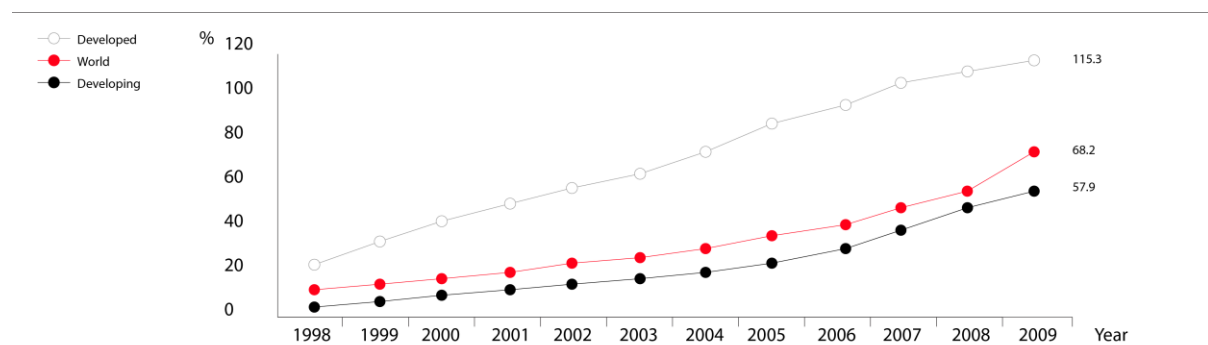


Figure 2.4 Mobile phone subscriptions per 100 inhabitants (ITU World Telecommunication / ICT Indicators database, 2009)

Since developing IT, innovative digital devices have produced various international issues. Developing communication devices has widely influenced social, industrial and cultural systems such as education and the economy through various commercial or free access mobile content (Servon and Pinkett, 2004). Therefore organisations developing mobile phone and mobile phone markets currently have a different weighting of importance; socially and culturally with other electronic products or home appliances.

2.5.2 Comparing the mobile phone industry to other electronic industries; Digital camera industry

This section will illustrate the appropriateness of the chosen research subject: mobile phone industry, through comparison with other electronic industries. This section will show distinguishing features and advantages of mobile phones through comparative analysis with other products under control by major regulations such as RoHS, WEEE, the Kyoto protocol and EuP, which give the largest impacts to industries, in particular the electrical and electronic global industries.

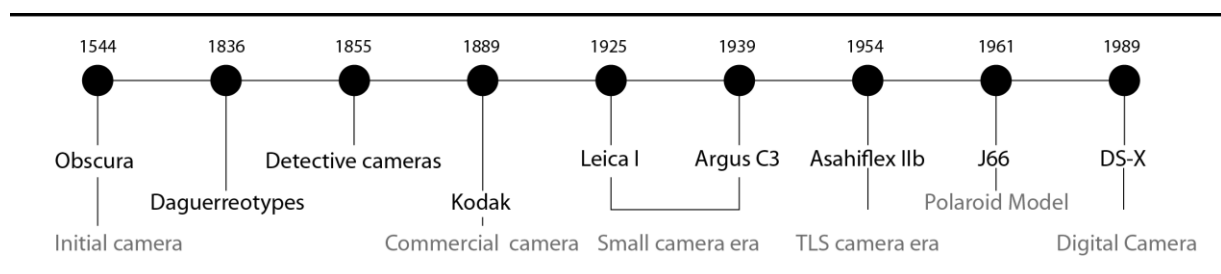


Figure 2.5 Roadmap of camera development (Wikipedia, 2013)

According to this roadmap, the history of the camera is approximately 340 years older than mobile phones. Digital camera markets had sharply grown since 1990's when they were invented to replace the film camera markets and booming digital cameras stimulated the invention of the SNS (Social Network Service – <http://inventors.about.com/library/inventors/bldigitalcamera.htm>, Access date: 1. 11. 2013) with internet technologies however, with increases to the mobile phone camera specification, digital camera markets started to become stagnant and in 2008, the markets initially recorded minus growth

(<http://www.independent.ie/business/technology/digital-cameras-begin-the-fighback-against-smartphones-28957251.html>, Access data: 1. 11. 2013).

The camera and Imaging Products Association in Japan announced in 2010, that 1.18 hundred million digital camera were released globally in 2010, whereas these volumes were 0.7% lower compared to 2008. This recession came from reduced world digital camera markets, in particular handheld small digital camera markets which were 90% of the entire digital camera industry. CIPA also estimated digital camera markets will reduce by more than 42% until 2013 through the convergence with mobile phone and high-end mobile phone camera releases.

Despite this, the amount of environmental impact generated from waste digital camera could not be found in the research, however comparing the global mobile phone market size and average product lifespan to the digital camera, mobile phone industries could produce a much larger environmental impact (see chapter 2.3)

Strategy Analytics (SA, 2013), which is the US special list regarding market research, announced that Korea is the most expensive (2.5 times more expensive than the average world price) in mobile phone prices in 2013. However the Korean mobile phone consumers also recorded the shortest product lifespan (67.9% of users changed within a year). This means 7 out of 10 users changed their mobile phone in a year and SA estimated that Korean mobile phone change frequency would stay around 60%. Hence, Korea currently has a very high production rate for waste mobile phones and recycling rates could be under 40%. The reason for choosing the mobile phone industry as the research subject is that this industry has been controlled by the same international environmental restrictions shown to be one of the largest social and market impacts and the current recycling rate is very low compared to this (SA, 2013).

2.6 Why Korean mobile phone industry?

The mobile phone market has a very short history but the large market growth has been non comparable. Korean mobile phone markets started from 1988 and the initial model was a Motorola Dynatec 8000 (however, the first Korean mobile phone was developed in 1993 at Samsung economic research centre, 2008). At that time, the major purpose for using mobile phones was showing off one's wealth and furthermore, at that time, the mobile communication policy was incredibly strict (it required agreement for signal security and communication monitoring) through the Korean political system. However the size of the Korean mobile phone market ranked 7th in the world in 2012 and has major mobile phone manufacturers despite their short history (Samsung economic research centre, 2008).

To understand the Korean mobile phone market, one needs to understand: i) size and features of the Korean mobile phone market, ii) assessing major manufacturers and service providers, iii) studying their eco policies and iv) identifying marketing and design strategies. Through this research the author will provide background data for adopting eco design methods by understanding mobile phones and markets.

2.6.1 Global mobile phone key manufacturers in Korea

The purpose of this research is to assess the appropriateness of eco design methods by applying these methods to mobile phone development. To implement this approach, the research needed to establish a research field hence, the author selected the Korean mobile phone industry for the research for five reasons, explained in section 2.5.

This section explains the current statues of Korean mobile phone industry and will provide the background for appropriateness of the chosen research field. The amount of global mobile phone shipments has increased to 1.66 billion (increased by 8.8%) and among this 6.6 hundreds million products were smart phones. (Export-Import Bank of Korea, 2012). The Korean mobile phone industry started with the

Samsung TS1700 in 1993, which is 10 years later than the initial mobile phone development -Motorola Dynatec 8000 in 1983, however in 2013 the Korean mobile phone industries have 27% of the global mobile phone market (Gartner report, 2013).

In particular, the smart phone has accelerated market share for example, Samsung recorded 21.3% of the global market share in the second quarter of 2012 (Gartner report, 2013). According to Export-Import Bank of Korea 2012, the amount of shipment of Samsung mobile phones has increased to 100.4% in the third quarter of 2012 comparing to the same quarter of 2011 and this volume increased by 8.5% from the second quarter of 2012. Furthermore, the mobile phone takes second place (24%) of the entire exports from Korea in 2012 (Ministry of Culture, Sports and Tourism 2012).

The mobile phone industry ranked 5th for the entire Korean exports and this amounts to 18.5% (KOTRA, 2010) of the Korean annual trading. That means the mobile phone industry in Korea has taken a significant place in the Korean economy. According to this, the Korean government, markets and companies have used great effort to position their relative dominance and continuously improving the Korean mobile phone industry. Furthermore, they recognised the importance of environmentally friendly issues as the most significant factors in the future to hold market position and manufacturers and service providers have found an effective ecological countermeasures for this (Jae Kyung Kim, 2013).

2.6.2 Ethnographic approaches

Ethnographic approach is a research method regarding an ethnic group or culture of that group.

Ethnographic approach is useful in determining how an individual behaves in a group and how culture is derived from that group. (Educational dictionary, 2004).

However, in this research, this term shall be used to describe an advantage of an ethnicity.

The research target; the Korean mobile phone industry, was easier to contact (due to previous sector contacts) and this research required several levels of mobile phone manufacturers interviews (previous interviews and expert interviews). To implement these research approaches, the researcher contacted the different companies by three different methods depending on the level of participants needs i) using networks and personal connections, ii) sending official requirements and iii) requiring related organisations such as KIDP (Korea Institute Design Promotion). In addition, the author found that during undertaking the research that most Korean mobile phone manufacturers, who participated in this research, have major concerns re this research. To continuously export products and maintain market share, these companies know that they should have more effective solutions to deal with environmental restrictions, than they currently possess.

In conclusion, the reasons for selecting the research target as the Korean mobile phone industry for the study was that i) it was easier to contact interviewees compared to other countries ii) the appropriateness of Korean manufacturers becoming world class in the mobile phone markets and iii) Korean mobile phone manufactures have larger concerns for Korean economic future; the Korean economy depends on over 70% in trade (Exports and imports, Bank of Korea, 2012) and environmental issues and possibility of applying this research in the future.

2.5.3 Summary

In conclusion, the reasons for establishing research targets for the mobile phone industry, especially the Korean mobile phone industries are below.

i) Globally, the mobile phone industry has been sharply developing and higher market and consumer's concerns, therefore, feedback about new products from manufacturers, distributors, retailers and markets can be much faster than other general products.

ii) The amount of waste from single mobile phone makes a tiny environmental impact however, in 2013, 6.8 billion users (billion mobile-cellular subscriptions, 2013) used mobile phones globally and this volume is the largest amount in a single product

group. Moreover, mobile phone product lifespans can be less than 2 years which is much shorter than other appliances, when comparing product lifespan to TV (5 years) and refrigerator (9 years) (Appliance Life Expectancy Chart, 2010). One can also compare amounts of waste that mobile phones produce; 4 million waste mobile phones annually (UNEP, Waste turning to new resource 2012). These issues means that the mobile phone can be a significant environmental considerations. Hence, treating and recycling waste mobile phones will be an even bigger issue (due to growth and expansion) and manufacturers have to prepare effective solutions for the future.

This research will show the wide range of solutions, approaches by innovated design direction use characteristic eco design methods and will consider a business enterprise at the same time. Innovated design direction in this context means a tool used in engineering, marketing, R&D modified by a designer.

iii) Recent mobile phone industries have influenced powerful international environmental regulations. This implied that most electric and electronic products will be controlled through environmental regulations and these environmental issues will be more heavily penalised in the future, therefore companies have to establish effective actions and processes for achieving the balance between economic and environmental benefit, sooner rather than later, to deal with current and future environmental restrictions. Consequently, the definition for an environmentally friendly product in this research is that it should have design value, marketing identity and enhanced production capabilities for reduced environmental impact and also generate economic benefit.

The researcher will implement cross comparison optimisation against investment limitations (maximum cost) to satisfy the market and social demands against environmental achievements.

2.7 Mobile phone industry eco policy

Currently mobile phone manufacturers and service providers have different eco policies and strategies. These eco policies and strategies reflect company philosophy, culture and current status however most of these companies who invested for environmental achievement do not carry out much R and D or develop new technologies. The greater part of these eco policies and strategies mention effectively dealing with eco restrictions, meaning companies consider that environmental issues do not produce economic benefit compared with other investment. Due to this, environmental product development has been a burden to manufacturers historically. Hence, environmental product development requires being more attractive to manufacturers and customers jointly (EPA, 2013).

In this section the author will show the current eco policies for mobile phone manufacturers and service providers by analyzing CSR (Corporates Social Responsibility) and finding features and strengths. Through this, it will provide background data for estimating their major concerns for environmental issues and consider current barriers in undertaking environmental product development.

2.7.1 Korean mobile phone manufacturer's eco policy

According to "Inventing environmental friendly design roadmap (Myung sik Choi, Jae Ho Kim 2011)", electronic manufacturers such as mobile phone manufacturers have their own method of environmental friendly policy. They take into account both characteristics of the market and their business philosophy to make new environmental friendly policies. In this report, it stated that Sony in 2000, LCA was the major idea when making environmental friendly policies and strategically applied it to the product. However, due to the deterioration of the market and the PS2 in Netherlands, the environment policy of the company became rather defensive. On the other hand, Samsung who used LCA three years later applied LCA to CSR. This publicized Samsung's way of environmental friendly policy. In case of LG, although they adopted environmental friendly method a lot later than others, but their environmental policy became bedrock in expanding LG chemicals.

In Inventing environmental friendly design roadmap (Myung sik Choi, Jae Ho Kim 2011) stated that there are leading companies and followers. Leading companies' ability in obtaining enough investment from market change, their status of being leading companies give them power to influence in setting up environment policies and obtaining skills to monitor relevant regulation in environment related policies distinguish leading companies and followers.

2.7.1.1 Samsung

Samsung built a vision of 'Creating New Value through Eco-Innovation' for environmental protection. The purpose of this policy suggests of new market values through undertaking environmental implementations in entire provider's activities such as product production, waste treatments and innovative network management. Samsung established 5 steps of 4 core tasks (2009~2013) that reduce greenhouse gas during manufacturing and use of the product, increasing the amount of environmentally friendly product development, extending investment in research on the environment whilst building green work places and reinforcing green partnerships with business partners to achieve this environmental business. To undertake these tasks, Samsung is investing 3.1 billion pounds (GBP) and these investments will use 1.78 billion pounds (GBP) for the environmental research and 1.32 billion pounds (GBP) for building new green work places until 2013. For their business partners, Samsung has supported them in attaining environmental certifications such as ISO 14001 and OHSAS 18000 and also supported various educational activities re green management and building green gas systems.

As climate change has become a significant international issues since the United Nations Framework Convention on Climate Change was held in 1992, Samsung established a management strategy system for greenhouse gas (GHG). Through this strategy Samsung will reduce GHG by 50% against sales until 2013 and increase energy efficiency by 40%. Furthermore, Samsung built the GHG reduction facilities in Korean factories 2010 and reduced GHG by 31% compared to 2008.

These environmental efforts are based on a strategy for developing processes, which more effectively deal with new environmental trends, which lead to global

marketing. Figure 2.6 shows a process consisting of 4 stages, each has a different environmental role however the strongest distinguishing facts are that it tries to connect different issues; 1) it is focused on various issues from the economic, social and technology for defining problems and current issues, 2) the process analyses the various risks, 3) it diagnoses their current capacities and status such as investment size, technology milestones and market awareness and 4) establishes a customised strategy for each task or requirement.

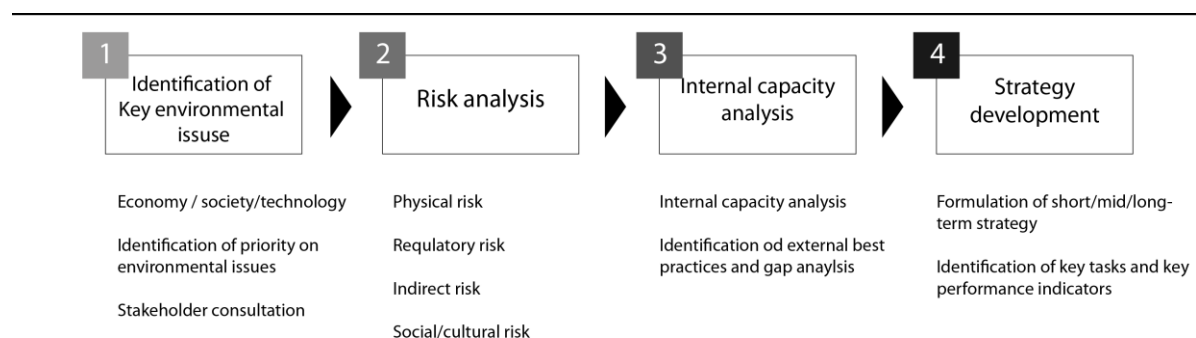


Figure 2.6 Samsung environmental product development process (Samsung CSR, 2013).

In conclusion, Samsung recognised that the environmental issues should reflect various markets' and consumers' demands to develop effective results and has implemented diversity for environmental approaches to reduce environmental impacts such as GHG.

2.7.1.2 LG electronics

LG established a significant environmental task force team that have 'eco design commitment', 'a research centre for analysing toxicities', Green partnership certification' and 'restrictions of toxic materials in entire products'.

To survive in EU markets, which are currently the 3rd biggest market for LG, they have to deal with RoHS restrictions in using 6 toxic materials (more information in chapter 3) which became effective from 2007 because looking at historical examples, if the products contain restricted materials, the providers or manufacturers have to redeem every product, which is complex and expensive however, a larger risk than

this is the damage to company reputations, therefore, LG electronics, through internal Eco design commitment, established new company systems for dealing more sensitively with environmental issues, they employed environmental experts, building eco design systems in their design department and developed eco technologies with long and short term roadmaps. Since these environmental investments have been accomplished, LG succeeded in securing eco technologies and their new materials fulfilled environmental restrictions over a year before restrictions became effective.

In summary, LG established a wide range of internal environmental systems. However looking at the entire environmental approaches, LG has not used a particular ecological method for design or evaluations. This fact shows LG is more focused on establishing systems and developing new materials whereas examples implementing eco design using newly developed materials or undertaking environmental quantitative evaluations could not be found.

2.7.1.3 Pantech

Pantech has participated in the 'Korean recycling regulation of manufacturer's responsibility' since 2005. To implement this regulation, Pantech built a partnership with 'Korean electronic industrial commitment', with an environmental outsourcing organisation collecting waste electronic products and recycling them in Korea in 2004. To increase the rate of recycling, Pantech made 76 collection points centred on after service centres for waste mobile phones and also make effective environmentally friendly mobile phones, Pantech established an eco-design manual (figure 2.7) based on an Eco checklist (more information about Eco checklists in chapter 3) and applies from the planning stage.

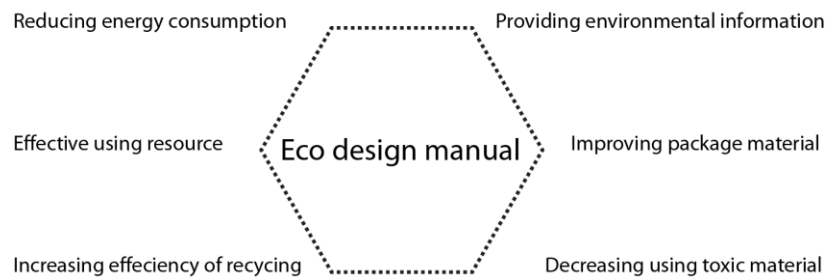


Figure 2.7 Pantech environmental policy (Pantech CSR, 2013).

Such efforts can be reflected in Pantech's cultural identity that a serious functional side rather than emotional or aesthetic approach can be seen, therefore an Eco design manual centre on the R and D department. This manual focuses on limited areas and adopts narrow categories from the Eco checklist, which only considers enhancing recycling rates, reducing toxic materials and package recycling.

However, this Eco design manual has not been applied or have any difficulties in being applied to mobile phone development but considers previous products from Pantech, it has not used distinguished ecological materials or applied innovated recycling capability for mobile phones. From mobile phone trends to the smart phone, this manual only focuses on using various eco materials or changing assembly structures will be more complicated, hence applying this manual to mobile phone development requires changes and further development.

2.7.2 EU and other major mobile phone manufacturer's eco policy

To stimulate consumer purchasing in eco-friendly products in the market, many countries have undertaken national policies. In 2001, Japan initially established a regulation for 'Buying Green products' whereby public institutions have to fulfil a standard percentage of buying environmentally friendly products and Taiwan, China, Australia, New Zealand and Korea followed suit. Europe established similar regulations in 2000 however this is only a recommendation. On average a government procurement market takes 10~15 % of GDP moreover, this market can strongly influence private markets. IPP (Integrated product policy) in Europe has tax support policy such as reduction of VAT (value Add Tax) for environmental friendly

product and furthermore, WTO (World Trade Organization) discussed abolish the tax on environmentally friendly products including traditional environmental management requirement products, eco -friendly home appliances, green cars and eco-friendly energy in Doha development agenda 2001.

In summary, these various efforts are focused on i) stimulating the environmental markets, only for considering the environment however, this can be most related to economics for international manufacturers and markets have to find and extend to new types of markets particularly electronic products and automobiles. ii) Increasing environmental markets, each country has its own tax support regulations or support strategies, which reflect national current circumstances. Government intervention can be an effective method for highlighting environmental issues, such as the requirement of a wide range of participation and higher social and economic concerns therefore many advanced countries and international organisations have undertaken their own supporting plans which influence the private markets and manufacturing industries.

2.7.2.1 Nokia

Since the mobile phone industry became a powerful global market, Nokia has a large regular customer base and are still ranked in the top 5 for global market share. Despite having this powerful status Nokia announced in 'Nokia world 2009' that their mobile phones would change from centring on innovated functions to 'Green issues' within 2 years and through such as these environmental efforts Nokia has the reputations of global environmental achiever. Kirsi Sormunen who is vice president of corporate responsibility at Nokia stated that Nokia have innovated through their ecological product policy from manufacturing processes that do not use any toxicities to recycling and collection systems. In 2008 Greenpeace evaluated global IT companies and Nokia ranked 1st with 7.3 points from a possible 10 on their eco score. The noteworthy fact is that Nokia got the best points from developing toxic material reductions and the Nokia 5140i model, fulfils the entire current international environmental legislation re material restriction when it came to the market in 2005, which is before the enforcement of RoHS (KOTRA report, 2009) moreover in 2007

this included the removal of PBB (poly bromo biphenyl) and PBDE (poly brominated diphenyl ethers). (Jang sung Kim, 2012)

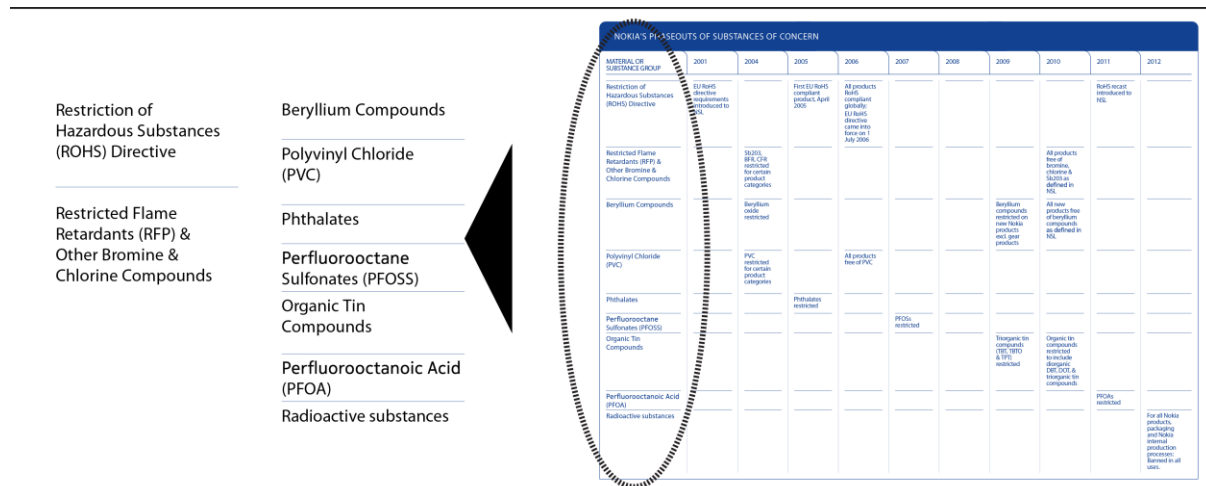


Figure 2.8 Nokia environmental management tool kit (Nokia CSR 2013)

According to Nokia CSR established a correspondence manual for RoHS and REACH before these regulations were officially enforced. In figure 2.8, Nokia developed an eco-friendly product tool kit with a matrix covering current major regulations, however this only focused on the management of using particular materials and compared reductions year by year.

2.7.2.2 Motorola

Motorola developed a total environmental system, which controls and reduces environmental impact within each stage of the product lifespan for production, use, distribution, and supply chain and end-of life. Based on this system (low-impact and end-of life solution), Motorola created a Green Innovation program for their environmental design strategy aimed at reducing their carbon footprint to half by 2012.

The Green Innovation program considers these facts;

- Use environmentally preferred materials
- Increase the amount of recycled materials used
- Improve energy-efficiency

- Reduce packaging
- Increase the recyclability of products

The features of this strategy are i) the program was very focused on the purpose of implementing environmental approaches, ii) to achieve this, Motorola undertook environmental quantitative evaluation (LCA) for production, usage and disposal with the new smart phone (Droid RAZR smart phone and Droid XYBOARD 10.1 tablet) in 2012. This example is the purpose of implementing LCA, which indicates that for both products the large majority of the impact occurs in materials and manufacturing rather than other stages, manufacturing impact accounted for 92 percent and 88 percent of the total product footprint for the DROID RAZR smartphone and the DROID XYBOARD 10.1 tablet, respectively. iii) Motorola is also implementing in-house materials regulations to restrict using brominated flame-retardants (BFR) and PVC or phthalates.

However, these strategies have similar approaches to other mobile phone companies and only focused on applying new materials, simplified packaging design and increasing recycling percentages to reduce environmental impacts.

2.7.3 Summary

In the environmental policy for current global mobile phone manufacturers, the companies can be divided to undertake strategic approaches through the implementation of qualitative diagnosis to develop foresight for international environmental legislation and changing markets such as Nokia, developing environmentally friendly products through innovating environmental technologies and using materials like Samsung. Since the enforcement of RoHS in 2006, many major manufacturers have invested more to develop and find new eco materials as an alternative to restricted materials. However, most current and previous mobile phones that were developed by these major companies could not effectively appeal to consumers from an environmental perspective and these products only fulfilled international environmental standards, where mobile phone manufacturers also satisfy economic activities.

Therefore most current mobile phones reflecting eco-friendly approaches, only focused on recycling and using less environmental impacts materials, through these approaches, consumers may lose environmental interest. In conclusion, to achieve eco-friendly product development in market and production, the eco-friendly products have to reflect environmental impacts such as energy efficiency, usability, disposal and materials rather than only following current legislation and also companies have to consider long-term environmental achievement through established eco design policies, assess the balance between environmental achievement and marketability and reflect consumer demands and realise productivity efficiencies.

2.8 Eco design in mobile phone industry

Currently many manufacturing industries have been trying to produce innovative environmental achievement such as using alternative energy and light-weight materials in the automobile industry and electronic industries have made a few innovated eco products that applied minimised production processes and use of new eco materials. Innovative new eco materials have dramatically increased recycling percentages and further reduced environmental impacts compared to previous models and this has influenced the creation of new paradigms for environmentally friendly markets and provide a new experience to make consumer's insights shift from campaign oriented to economic benefit.

This section will illustrate current environmental mobile phones and contemplates limitations of current eco-friendly mobile phone developments through these examples.

2.8.1 Eco design in mobile phone development

-Blue Earth phone (Samsung, 2008)

Samsung developed a touch type environmentally friendly mobile phone in 2008. The Blue Earth phone, which targeted EU markets, applied environmentally high technologies such as recycling approaches and solar energy.



Picture 2.1 Samsung Blue Earth Phone (2008)

The solar panel is located on the rear side of the mobile phone and can charge in any place at any time. To implement environmental development, this mobile phone manufacturing processes followed eco-friendly production process and used recyclable packaging. The biggest achievement of this mobile phone is it used 70% of recycled PCM (Post Consumer Material) from waste pet bottles for the mobile phone housing. Using PCM for the mobile phone housing can lead to a reduction in the amount of materials and also decreases CO2 emissions and does not use toxic materials during product manufacturing.

3110 Evolve (Nokia 2008)



Picture 2.2 Nokia 3110 Evolve (2008)

The Nokia 3110 Evolve is produced by non-toxic natural plastic, extracted from plants. This also reduced environmental impacts by applying recyclable materials in the housing and a non-toxic power chip set, low voltage graph card and battery. Specifically, over 50% of the housing components can be changed to other modules and through this feature would extend product lifespan through easier repair and upgrade.

The Nokia 3110 Evolve innovated minimised charging technology so that it minimises energy consumption when the battery is fully charged the charger stops energy consumption automatically.

-C901 GreenHeart (Sony Ericson 2010)



Picture 2.3 Sony Ericsson 3110 Evolve (2008)

The strongest feature of the Sony GreenHeart was its success in CO₂ emission reductions by 15% less than current mobile phones. This mobile phone applied bio plastic, which extracted oil from vegetables and uses at least 50% recycled plastic for the housing and keypads. To reduce energy consumption, GreenHeart applied low voltage displays. Instead of a manual book, this mobile phone has an electronic manual inside the mobile phone, which reduces over 90% of paper consumption. The Sony Ericsson C901 GreenHeart also comes with waterborne paint and the newly introduced MH300 greener headset in the box is made from 100% recycled plastic.

2.8.2 Summary

The previous sections showed various examples currently developing environmentally friendly mobile phones. The examples of eco mobile phones are the most advanced products in environmental perspectives and to achieve environmentally friendly status, these products applied high environmental technologies such as using solar power and alternative materials. In addition, these major companies used their own environmental strategies for product development e.g. in the case of developing the Blue Earth Phone Samsung used 'identified by technology innovation', which is the motivation for Samsung for environmental product development and also the Nokia 3110 Evolve showed significant expertise for Nokia to become a leading company with environmental legislation applying accumulated environmentally related experience to product development and expertise for understanding international environmental regulations.

However, these current advanced environmentally friendly products have a gap with current major sellers therefore, these types of product have very short market lifespan and are still undertaking campaigns so consumers could not objectively compare products. To achieve effective appeal to the consumers through environmental products, it requires i) the environmental issues have to apply to general products rather than campaign products which would influence changes to the market for more environmentally friendly products and ii) this change will provide environmental awareness, where environmental issues are not optional but essential drivers.

Summary of chapter 2

- Single mobile phone has only made the small amount of waste however 6.8 billion users used globally and this volume is the largest amount of single product group
- 8 eco design methods (Anti-fashion, Durability, Upgradability, Recycling, Energy saving, Reduced material, DfD, Reduced function) has different concepts of approaches and solutions
- Korean mobile phone manufactures (Samsung and LG) ranked the highest sellers and producers in the World
- Major influences of international environmental legislations are RoHS, WEEE and Kyoto protocol and leading manufactures can influence or stand on positive position
- The paradigm of environmental preservations have changed to more emphasize about producers' responsibilities
- International environmental legislations have become more specific and narrow focus on the markets and contents

Chapter 3. Overview of eco design methods

Precis of chapter 3

- To determine features and contexts about each eco design method
- To explore the general historical issues for deducting difficulties about eco design methods
- To determine identify of eco design methods
- To establish the standards for categorising eco design methods to idea generations & quantitative evaluations
- To build the standards eco design methods in product lifespan & different methods' approaches

Before exploring eco design methods this section shows what eco design guidelines are and what major objectives can be achieved by using eco design. This wide range of eco design guidelines may describe the contexts and features of eco design methods and provides optimistic goals of eco design.

A major concept of eco design is that it combines multifaceted aspects of design and environmental perceptions. The concern of design for the environment is to create sustainable solutions that fulfill human needs and desires.

In professional literature authors, R. Karlsson and C.Luttropp (2006) have defined eco designs as:

“products, services, hybrids or system changes that minimize negative and maximize positive sustainability impacts - economic, environmental, social and ethical - throughout and beyond the life-cycle of existing products or solutions, while fulfilling acceptable societal demands/needs”.

- The established major arguments for eco design are (R.Karlsson and C.Luttropp, 2006):

- 1) Improving products and technological processes
- 2) Reducing costs through verification and modification of products at early concept stages,
- 3) Following customer changing needs
- 4) Creating new needs from customer requirements
- 5) 'Reduced material consumption', 'Energy consumption' and decreased product lifespan,
- 6) Product and packaging weight reduction (R. Karlsson and C.Luttropp, 2006)

- In reducing production and disposal costs, the eco design guidelines state (William McDonough, 2002):

- 1) Do not design products, but life cycles. Designers should design environmentally sound product life cycles.

Review all material and energy inputs and use of a product during its whole life cycle (from concept phase to cradle to cradle- 'cradle to cradle' William McDonough, 2002).

- 2) Minimum use of material. Designers should take care to rationalise resources and minimise material usage.

They can often reduce the amount of material by looking critically at dimensions, required strengths and production techniques. It can be beneficial to use materials that have a high environmental load per kilogram, if designers can reduce weight. This is particularly true for transport, where lower weight means lower fuel consumption.

- 3) Energy consumption levels are often underestimated. Designers should consider energy consumption at every stage of the product life cycle.

- 4) Increase product lifetime. Designers should design product longevity

- 5) Use recycled materials. Design recyclability into products, and use recyclable materials where possible. Reduction of new resources minimises waste (M.D. Bovea V, Pérez-Belis, 2012).

The eco design guidelines are a fundamental or ideal theory. Current eco design guidelines therefore only reflect designers' difficulties and conflicts. Designers should look for efficient processes and material usage.

A recent objective of eco design, which has similar concepts with environmental friendly design, sustainable design and green design, is that the eco designer should consider balancing social and human, environmental and economic benefits through the integration of traditional and ecological design approaches. Hence, the eco design method in this research will suggest how and what eco design approaches are the most effective to achieve these objectives (Korea Institute of Industrial Technology Evaluation and Planning, 2012).

3.1 Issues whilst developing eco design

This section will show: i) changing environmental design trends in different eras, ii) emerging development issues regarding eco design tools and a review of influences, iii) introduction of an understanding of historical eco issues for eco design development; and iv) the illustration of key ecological definitions in different eras.

There are a few progressive industrial designers who have had impact and influence on sustainability (Chochinov, 2009, Papanek, 1985, Papanek, 1995, Rams, 1995, Schmidt-Hellerau, 1912). These efforts indicate the importance of ecological issues related to design activities amongst pioneers of this field.

Recent studies from Japan (Ueda et al., 2003) and the USA (Davis and White, 2004) also found a high level of personal environmental awareness amongst industrial designers.

Wahl and Baxter (2008) demonstrated that the general designer's approaches to product development related issues offer great potential to include eco design in the product development process. Bakker (1995) found "the industrial designers could successfully contribute towards the incorporation of environmentally responsible

solutions in the product planning phase as well as in the later strict development”.

Bakker (1995) asserted those industrial designers establishing the product-planning phase as being “strategic” and those contributing to the strict development phase as being “operational”.

As such, eco design has been more strategically and systematically developed, so how have eco design tools developed through eco design history?

- **Era of recognition and environmental preservation importance (1960 – 1980):**

In the late 19th century, accrued Mormonism, rapid industrialisation and urbanisation and environmental activities were started through a variety of efforts for finding spiritual happiness and preserving public systems. Initially mentioned environmental issues were announced ‘greenhouse effect’ in 1896, Santa Arrhenius (1859-1927), who was a Nobel Prize winner asserted that ‘CO2 emission may accelerate the global warming’ in his journal ‘Arrhenius equation (1889)’.

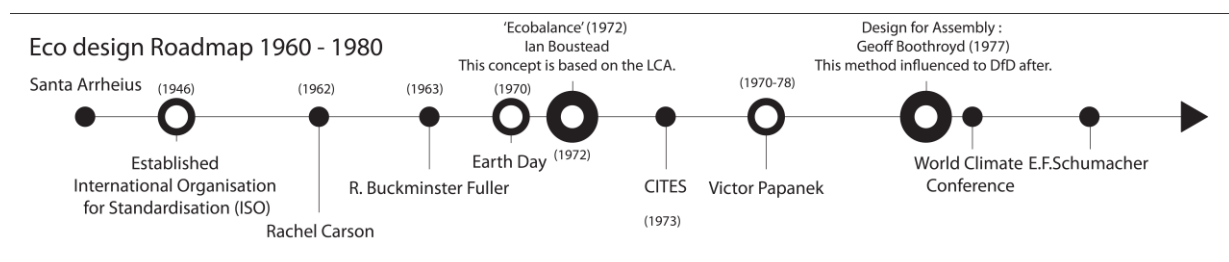


Figure 3.1 Early stages of Eco activities (1960 – 1980)

40 years later, in 1962, Rachel Carson (1907-1964) who was a US marine biologist published ‘Silent Spring (1962)’, which stimulating debate of ecological issues and impacted social consideration, until that time the environmental preservation efforts had only interested a small group of social pioneers.

R. Buckminsterfuller (1895-1983), who was a mathematician, architect, social thinker and designer, also invented ‘the Synergy concept’, ‘Dymaxion house’, ‘Spaceship Earth’ and ‘Earthain’, warned that indiscreet resource depletion might lead to the destruction of the Earth, in his book ‘Operating manual for spaceship Earth (1963)’.

Victor Papanek (1927-1999), who published 'Design for the Real World (1971)', looked at design differently. He asserted the most significant factors to preserve and coexist with the environment were a designer's responsibility. His advanced concepts have influenced various recent eco design concepts, products and theories. During a very industrially centred era between the 1960's and 1970's, the major concern producers and international organisations was the efficiency of production and increasing product quality.

At that time many international organisations developed the International Standardisation Organisation (ISO). ISO is one of the significant international organisations for environmental design area and it established the ISO 14000 series in 1996, called 'the environmental management' and leading to 'the Green Round era'.

ISO 14001 also established initial practical methods for achieving Environmentally Sound and Sustainable Development; ESSD at the Rio Summit (1992), also established Environmental Performance Evaluation (EPE), Life Cycle Analysis (LCA) and the eco labelling program (M.D. Bovea V, Pérez-Belis, 2012).

Eco design tools from 1960 to 1980

In this era, eco design and the eco product were not deemed critical issues. People were more interested in new products and technologies. However these social trends stimulated anti-materialism and a few progressive thinkers started to consider criteria other than material wealth. These activities influenced various initial environmental activities and established fundamental eco design definitions and guidelines (Tischner, U., Schmincke, E., 2000).

The key achievement of eco design at that time was establishing initial eco definitions and defining what eco design was theoretically. Although there were no examples of eco design tool development at that time, various considerations and theories influenced the development of eco design tools thereafter.

- **Era of shifting the movements of various global efforts
(1980 – 1990):**

Even though previous pioneers had asserted that various significant ecological issues were necessary to maintain human culture, consumers' major concerns were still on performance of new technologies.

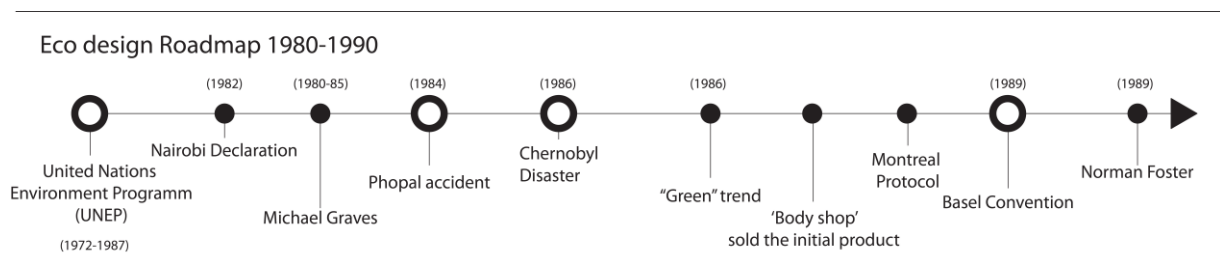


Figure 3.2 Era of shifting the movements of various global efforts

However, most environmental preservation activities had a turning point after global disasters. Two different 1980's global disasters were Bhopal (1984) and Chernobyl (1986); most international organisations undertook environmental systems development agenda however, compared before and after the disasters, the objectives and contexts for environmental issues were developed to be more restrictive for social responsibility.

For example, comparing the United Nations Environment Program (UNEP) in Nairobi, Kenya, 1982, and the World Commission on Environment and Development (WCED) in UN, 1987, UNEP presented 'the Declaration of Sustainable Development', which was a first attempt to minimise the gap between advanced and developing countries' perspectives. However, the declaration did not include enforcements and agreements. On the other hand, WCED reported 'Our Common Future (1987)', this segmented categories of environmental problems and defined each problem. Moreover, the Montreal Protocol in 1987 and Basel in 1989, established initial compulsory ecological restrictions to treat industrial waste and hazardous material, which was based on international environmental modern restrictions.

An increasing social and industrial status of design and increased concerns changed people's focus from material fulfilment to spiritual satisfaction, as a result of this

many industrial designers undertook eco friendly design. These aspects influenced the creation of various eco design areas; for example 'Green design' is focused on the environmental enlightenment. Whist, the Design Council, contributed design exhibitions in Design Museum, 1986 and tried to assert that green design was not “anti-industry”, and the “the greening of industry had gone further than most people imagined” (Richard Buchanan, Dennis Doordan and Victor Margolin, 2010).

- **Environmental preservation for economic benefit**

(1990 – 2010): Era of Green round

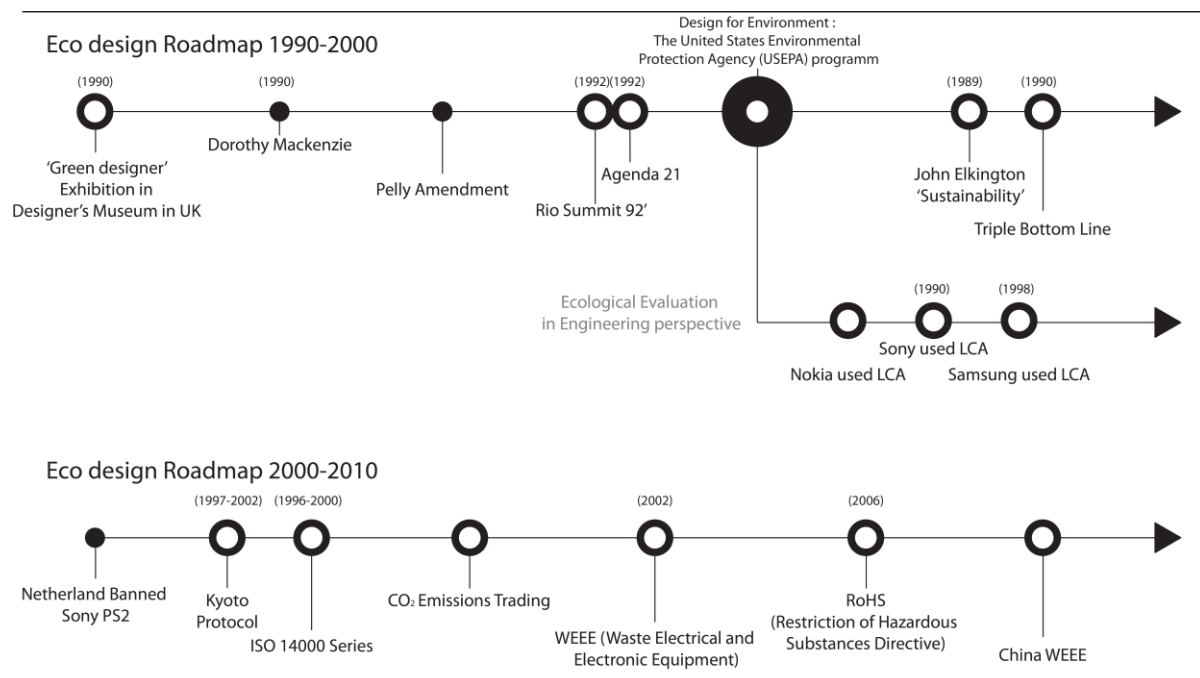


Figure 3.3 Era of Green round (1990 – 2010)

The 1990's eco design increased quantitative techniques. Companies adopted various new ecological techniques / technologies (such as recycling, reuse and alternative energy) and consumers recognised distinguishing factors of good quality products. Eco design in this era was defined as the innovative challenging era through various academic-industrial and government-industrial co-operations, which attempted to work to accomplish eco product development. Pauline Madge (1993) asserted that the role of first generation eco designers between 1960's and 1980's provided the fundamental guidelines to find the answers re 'how to achieve eco design?', therefore in 1990's, eco designers approached eco design through

intensified research using a critical perspective. These academic efforts increased social awareness and stimulated international organisations to react. This research established significant international eco regulations, which built the Green round, which focused on environmental preservation but also protected trading through eco regulations. For example, the Restriction of Hazardous Substances Directive; RoHS (2006) and Waste Electrical and Electronic Equipment Directive; WEEE (2002) had an impact on global economics by increasing providers' responsibility rates for recycling, reuse and recovery, particularly in the electric and electronic industries.

Eco design tools from 1990 to 2010

Since the presentation of the sustainability and Triple Bottom Line (TBL) by John Elkington (1987), eco design tools have rapidly developed. This is especially true for the principles of sustainability for environmental benefit, which may be connected to economic benefit. This stimulated companies and the focus of eco design was changed from public relations to generating economic benefit. In this era, social awareness dramatically advanced through increasing lifestyle quality, therefore Corporate Social Responsibility; CSR has been important as a marketing tool for instance, Nokia, who applied LCA to evaluate their own products initially and then followed Sony and Samsung by positively appealing to consumers.

3.1.1 Lack of communication between designers and other areas

Recent practical level definitions regarding eco products and eco product developments modifying specific parts or increasing only a few parts of the product to be slightly more eco-friendly achievement compared to current products rather than considering environmental impacts systematically. Likewise, eco design could also not consider environmental impacts or ecological systems as it was only used for eco design approaches, as small design part development of design direction or design concept additions (Hankinson and Breythenbach, 2011).

Due to a lack of communication and interpretation problems by different methodology approaches between engineering and design, for example, designers could not use the results from quantitative eco evaluation appropriately (Hankinson

and Breythenbach, 2011).

The designers undertook eco design experience by using eco design tools but failed because they did not recognise some features of these tools which were critical but required very high quality input from previous research (Lofthouse, 2006).

According to Reine Karlsson (2005) in his journal,

‘Eco design has to be based on a dependable ability to analyze, e.g. by means of tools such as LCA. To make a difference, the environmental information also has to be activated within the companies’ development processes.’

However, Hankinson and Breythenbach (2012) reported to undertaking LCA with design required environmental engineering knowledge and this aspect could isolate designers from eco product development.

For example, an EcoDesign Checklist is a substantial list of requirements to be added to an already taxing design brief. Many designers complained that the tools available did not show them how to do eco design (Bocken et al, 2011).

Although tools such as the LiDS (Lifecycle Design Strategy) wheel did help them to highlight the issues by quantitatively measuring results they needed to consider, there was no support provided to help them to take providing guideline further (Lofthouse, 2006). Designers, particularly industrial designers have used many resources in designing. Most types of background data and design resources have become very abstract through logical & inspiral images hence the eco design tools introduced in this research are very design oriented compared to other eco design tools.

Tischner and Charter (2001) who also reported relation to these issues re eco design materials, which is often widely dispersed, making it time consuming for the collection of the data. The report showed examples about designers who had used the LiDS wheel and the Eco Re-Design programme asserted that they felt alienated

and overwhelmed by them, as they were asked to consider issues, which were irrelevant to their work.

Although it emerged that the tools were not being used in their correct context, it showed that asking designers to consider irrelevant issues (such as the environmental impact of the extraction of selected materials) could put designers off eco design. Due to the fact that the tools were not being used in their correct context, would be detrimental for the uptake of designers using eco design tools.

Consequently, the eco design area has various barriers such as an interpretation problem with clients and other areas and a higher burden from long term projects which designers feel unsuitable for use within the industrial design area. Eco design needs to positively adopt eco design data, which originates from engineering and other areas through planning. It also demands material & manufacturing experiences to understand production and needs disposal processes. For these reasons undertaking eco design methods by only industrial designers who have not had any related educations or experiences for developing eco design products, which exceed or fulfil many quantitative standards in other areas, is very difficult (Tischner and Charter, 2001).

Industrial designers have often reflected their personal experiences or subjective values in design, for instance; famous designers have occasionally designed products, which only considered the impact of strong messages rather than marketability and productivity.

The necessity of developing environmentally friendly products have rapidly increased since the Green round was originally impacted on by a variety of environmental pollutants such as Greenhouse effects, which established the various international environmental policies and extended the consumer's eco awareness.

However, there have been many failed experiences that could not achieve marketabilities or productivities against investment cost and time with traditional, social and environmental demands; in fact industrial designers still have pessimistic opinions due to these difficulties.

According to a report by Hankinson and Breytenbach (2012), they asserted four major barriers to accomplish eco-friendly product development in the industry.

The first issue is 'cost'. Many clients frequently attempted sustainability or eco design approaches in their new product development; however the investment cost crossed over 'bottom line' estimations (Hes, 2005).

The cost problem does not only mean production costs but includes reoccurring lack of investment. This report uses two metaphors; the client as a sprinter, who wants to get instant benefits or visualised results, and the long term achiever as a long distance jogger as most eco product development needs longer to develop and require constant management. The asserted character of eco design has mostly been accomplished by long-term projects therefore many eco design projects have not been able to achieve mass production, which sprinters wanted or even fashionable products (Hankinson and Breytenbach, 2012).

'Education and inexperience in sustainable design' is the second issue. Since the introduction of eco design tools into the industry, they have developed in engineering and marketing areas but designers had little opportunity to learn and experience the tools. For example, in the case of LCA, which is currently applying widely as quantitative environmental evaluation against various environmental impacts in environmental engineering area a search for LCA as a keyword into a search engine will bring up many engineering or marketing texts and documents but not many adoptions of LCA in the design area will be found (Davis, 2001).

According to a report by Hankinson and Breytenbach (2012), 50% of industrial designers do not have appropriate eco design experience within eco design specialisms and also most of them have only experienced eco design theoretically.

The third key problem is 'Material'. Recently CMF (Colour, Material and Finishing) or CMFP (Colour, Material, Finishing and Pattern) has become the most significant factor in modern design therefore developing new eco materials can be the most effective achievement in the eco design area. Currently many global companies show their eco policies and eco products as 'Green Washing' which means the

company markets eco efforts as a PR effort. However to achieve eco products, which can reduce environmental impacts, bring economic benefit and social advantage, one needs to reconsider materials and manufacturing processes.

The fourth barrier is the 'Client' (Hankinson and Breytenbach, 2012). To develop research questions and review the current ecological situation in Korean industry, the author undertook primary interviews with manufacturers and marketers. Common pessimistic answers were that 'eco design cannot have marketability' or 'nobody would pay for eco products'. Many global manufactures have their own unique policy and strategy for developing eco products, and various CSR (Corporate Social Responsibility) reports and their PR presented what and how they had made efforts to reduce their environmental impact (Davis, 2001).

Through the research, the researcher found, the weakest is the development of eco products, which demand high production costs but may only return a small profit. As you can see from the FGI interviews at the end of this research, marketers said that a few innovated optimisation products such as 'Apple's I-phone' and 'Motorola's Startek' can achieve Anti fashion, which is an emotional eco design approach, however on the other hand these products can be applied to any successful examples. In hence, this author found that successful eco design should involve the variety areas' efforts such as innovative marketing, new mechanical approaches and sustainable investments.

Another example is looking at the recycling approach, it requires one of the highest investment levels to achieve this as it needs to establish a system for collecting, evaluating, cleaning, recycling and educating and also needs government and international regulations. Consequently, such complexities can be the reason to disrupt the adoption of 'recycling' to a wide range of industries and it still undertakes only the collection of natural materials

In such cases, the client usually expects the eco product could be the silver bullet to solve their problems, for example refurbishing a company image, undertaking PR, taking into the market and profit making, however achieving these advantages

through the eco products may not be possible at this time (Hankinson and Breytenbach, 2012).

On the other hand, in case the industrial designer has to consider alternative ways to carry out effective communication, eco design approaches and processes have very different structures to industrial design particularly product design. Eco design needs more multidisciplinary approaches and that demands more time for planning and communicating and more cost for designing and producing (Roozenburg et al, 1995).

To sum up, to achieve eco design, i) the client has to understand exactly the eco design definition and benefits (Hankinson and Breytenbach, 2012), ii) the designer also needs to improve communication skills and broaden experiences (Roozenburg et al, 1995) and iii) awareness of market and consumer needs and be ready to import it (Bakker, 1995).

3.1.2 Barriers to manufacturer adoption

- Complex industrial systems in eco design

To understand the difficulties of applying eco design tools to manufacturing, there is a need to recognise complex industrial and technological systems whose specialisms have not really been taken into consideration with eco design and eco innovation: these are industrial systems where complexity induces major issues in terms of modelling, prediction or configuration.

Moreover, an environmental dimension to the traditional definition of an engineered system, François Cluzel, Bernard Yannou, Dominique Millet and Yann Leroy defined a complex industrial system in the sense of eco-design as (Cluzel et al, 2012):

- A large-scale system in terms of subsystems and components, mass and resource usage,

- A system whose life cycle is hardly predictable at a design level in the long-term, in particular its lifetime, upgrades, maintenance and end-of-life,

- A system whose subsystems may have different life cycles and different obsolescence times,
- A system in close interaction with its environment (super system, geographic site, etc),
- A system supervised by human decisions and management.

Regarding eco design, the significant problem with such delayed development is that the clients' narrow specifications or company regulations and standards largely limit the ability to radically innovate, as only long-term proven technologies are used.

Thus the challenge associated with an eco-innovation or eco design approach is whether to identify a set of reliable incremental eco innovative projects, and/or to be able to make possible radical eco innovations acceptable to the clients (Cluzel et al, 2012).

3.1.3 Summary

Compared to other academic areas, the study of eco design has developed very slowly. For this reason, eco design and eco products could not appeal enough to its environmental expertise and reliability for customers and corporates to have expectations regarding eco product developments and corporate responsibility (Sweatman and Gertsakis, 1997). At the same reason, this research had the similar difficulties that i) the researcher has only design base of knowledge therefore the author required to learn the technical jargon about environmental engineering and business and ii) this area, which is studying relationship between eco impact and business opportunities, had not many advanced research hence, this research spent longer time to collect fundamental data and implementing basic research.

Previous research shows most designers, particularly industrial designers felt it difficult to communicate that isolating from technology knowledge and designer's tightfistedness of consulted with other areas (Davis and White, 2004), especially

engineering and marketing as in order to accomplish eco design and eco product development this demands a wide range of discussion and efforts.

These industrial cultural characteristics have disturbed opportunities to understand and experience eco design practices, and designers have become more isolated from the eco design field. Hence, the eco designer, who can produce design results through the use of quantitative eco evaluations, opens up opportunities but other eco designers and markets have been negatively influenced by these problems (Davis and White, 2004).

However global corporations have recognised how significant eco markets are for the future and have tried to find the marketability for eco products. Moreover, they have highlighted the importance of training for eco design experts to help deal with reinforcing international eco regulations (Johannes Behrisch et al, 2010).

In conclusion, although cultural or characteristic barriers exist, markets will continuously require the advent of the eco designer, finding solutions for effective communication methods and establishing ecological evaluation methods for design results.

3.2 Eco Design methods

The concept of Eco Design (or Ecodesign) has recently been introduced compare to other areas of interest such as high and biotechnologies. Initial concepts for Eco Design were very abstract and emotional approaches, however, in the 1970's "Earth Day" provided a turning point in this area, for many environmental experts and NGOs developed current eco design models based on more realistic and practical eco design concepts.

Below is a definition for eco design (related to environmental friendly efforts) by designer Victor Papanek. He suggested "industrial design was murdered by creating a new species of permanent garbage and by choosing materials and processes that

pollute the air” in his book ‘Design for the Real World: Human Ecology and Social Change (1971)’.

Fuller demonstrated in his book named ‘Operating Manual For Spaceship Earth (1968)’ more regarding this and introduced how design could work in a central role in identifying major world problems between 1965 and 1975. Fuller (1968) mentioned i) Review and analysis of world energy resources, ii) Defining more efficient uses of natural resources such as metals and iii) Integrating machine tools into efficient systems of industrial production.

Recently eco design has become one of the significant future industries, for example large sized companies have recognised the importance of environmental responsibility for their long-term future success. These experiences related to eco design supported a competitive advantage by reducing the production costs and waste management, encouraging innovation in products and manufacturing processes and simplification in attracting new customers (Hong-Yoon Kang, 2002). In particular the electronics industry has concentrated on international laws and regulations to implement product responsibility, especially focused on the ‘end-of-life’ of a product because of its’ rapid technological rate of change, subsequent high rates of product obsolesce and growing problems from waste products throughout the world (Hong-Yoon Kang, 2002).

Since the development of eco design concepts, various engineers, marketers, anthropologists, ecologist, NGO and intellectuals have defined eco design, environmental friendly design or sustainable design. Here are a few examples of those definitions, which have a different focus.

The concept of Eco Design developed by the World Business Council for Sustainable Development (WBCSD) at the Rio Summit was the culmination of a holistic, conscious and proactive approach. The aim of eco design is to provide possibilities for products or service design and minimising its impact on the environment. It has influenced every stage in the product life span: raw material

extraction, production, packaging, distribution, use, recovery, recycling, etc (Jeswiet and Hauschild, 2007).

According to Karlsson and Luttrupp (2006), “Sustainable solutions are products, services, hybrids or system changes that minimise negative and maximise positive sustainability impacts - economic, environmental, social and ethical - throughout and beyond the life-cycle of existing products or solutions, while fulfilling acceptable societal demands/needs”.

Eco Design can be defined to “a new way for developing products where the environmental aspects are given the same status as functionality, durability, costs, time-to-market, aesthetics, ergonomics and quality. Eco design aims at improving the product's environmental performance and may be seen as a way of developing products in line with the concept of sustainable development and life cycle thinking” (Hauschild et al, 2004).

Recent eco designs and eco products concentrate more on practical level (see section 3.1), such as developing, evaluating and generating ideation tools rather than conceptual philosophy. It provides theoretical background and appropriateness for creating eco design tools, which will be explored in this research. The Eco Design concept was created by questioning why people's definitions of eco design tools is segmented and has been developed through realistic and practical experience but started from “how” and “what”.

Tingstro and Karlsson (2005) wrote a paper entitled, “The relationship between environmental analyses and the dialogue process in product development” which introduced a new perspective for eco design tools such as LCA. It demonstrated that by rigorous analysis, this tool could activate a company's development processes. The major issue within this paper was describing how combinations of different types of support for eco design progress this within companies.

“Handling trade-offs in Eco Design tools for sustainable product development and procurement” written by Byggeth and Hochschorner (2006) investigated whether different eco design tools provide decision-making help or not. The researchers

stated that most tools tend to have a “Jeopardy” approach because very often in eco design one has to make selections between alternatives, which seem nearly equivalent. The tools that are reviewed can help the product design team to sort through the options in a more effective manner (Karlsson, Luttrupp, 2006).

To develop eco products to lower environmental impacts, a product designer needs specialised tools that require information, teaching aids, guidance and examples regarding eco design. Since designers have not had enough knowledge in this area, they are unable to integrate all the necessary environmental functionality (Lofthouse, 2006).

The eco design tool also has a very similar work process to traditional design processes.

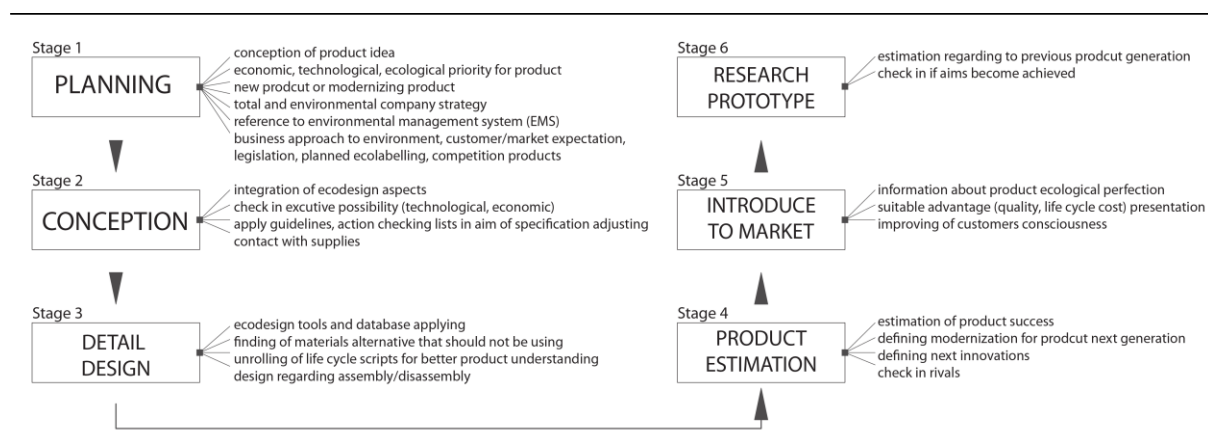


Figure 3.4 Schema eco design process (Schischke et al, 2005)

Referring to Schischke announced ‘Schema eco design process (2005)’, to complete eco design more requires quantitative data from variety environmental tools such as check list tool and evaluation methods rather than traditional industrial design process that are based on qualitative addresses. This assertion can be in accord with the research strategy and context therefore the author adopted the context to establish the research framework.

Figure 3.4 shows that each eco design tool impacts on a different level of design process. It explains that eco design tools are also considered from a planning and is the same as a design tool approach. That means eco design does not only undertake alterations to housing shape or reduce functionality but also needs to

focus on suggesting total solutions, including; ecological systems, reducing potential environmental impacts and simplified manufacturing processes. The planning in the eco design planning level can be a guideline to create eco design concepts to minimise eco impacts and can be realised through using traditional design and quantitative eco planning methods.

The biggest difference between traditional design processes and eco design methods is the verification stage in the early stages. The eco product development tools generally designed with more focus on evaluation purposes, such as comparing businesses or creating ideas against environmental objectives. The early evaluation may disrupt the generation of creative thinking and prevent the pursuit of innovative ideas (Osborn's terminology, 1957). However, some evaluation tools such as the Eco Compass and Eco Design Checklist may be used to assist with eco ideation in practice (Charter and Tischner, 2001) because help to provide qualitative resources to assist group brain storming and other concept generation are specifically for this purpose and use the Standard Design Process Form (SDPF), Product Ideas Tree (PIT) and diagrams in combination with eco-design tools (Jones et al. 2001). Eco design methods or processes need quantitative and qualitative evaluation to prove environmental impact and this can be shown to customers through fulfillment of eco standards or by gaining eco certifications.

To sum up, eco design tools fulfill several factors:

According to these references they have four uses: i) environmental analysis and evaluation, ii) selection and definition of priorities for improvement, iii) support the generation of ideas and design decisions and iv) coordinate other criteria (Bhamra, 2003).

However, it also considers them by their scope: i) focusing on a particular environmental objective, ii) product development with a lifecycle perspective, and iii) designing for eco-efficiency with the integration of sustainability (Vezzoli, 2003). Design tools can also be divided into two types: quantitative and qualitative. The first requires large amounts of information and time for their use; unlike qualitative, which

is simpler, requires less information and time, and allows easier integration into internal product development.

3.2.1 Definition of eco design tools

As social awareness is rapidly increasing regarding eco friendly issues and economic value, designers' responsibilities have become more significant since the environmental problems became controversial global issues in the 1990's.

Many recent international eco regulations and governmental bodies, environmental pressure groups, retailers and consumers have directly impacted on consumer goods manufacturers, and as such, this pressure has increased. Although there are increasing public concerns and market requirements, there are not many existing eco design methods for designers.

Eco design reports or articles often show many eco design tools, which have failed to be applied or used within design processes. Existing tools are focused on strategic management or traditional analysis of products instead of the design area. Moreover, these problems have faced by designers who have not used these tools in the industrial design area and have created 'their own way' for undertaking eco design (Lofthouse, 2006).

The difficulty with this is that many eco design tools demand industrial designer work with integrating knowledge about environmental technologies, undertake research projects or collaborate through academic research projects. General industrial designers do not have experience of working with eco product developers; neither have they had opportunities to learn decoding eco analysis results.

As there are many definitions of eco design tools, these problems may have occurred due to functionality problems, containing unknown characteristics and also requiring quantitative factors in applying tools.

Karlsson and Luttrupp (2006) defined eco design as being focused on the integration of environmental perspectives for product development, and suggested that eco

design tools ought to be made available to designers during the product development process. The Integrated Product Policy (IPP) approach (COM 68, 2001; COM 302, 2003) and Eco Design Directive (2009) asserts that eco design product needs to be considered with all environmental impacts from the earliest stage of its design and apply systematic ecological approaches for balancing against traditional requirements during the product development process (Bovea and Perez-Belis, 2012).

This section presents a number of methods for environmental evaluation methodologies and integrating approaches of such environmental evaluations into the design process.

Byggeth and Hochschorner (2006) found standards to divide the tools by analysing fifteen eco design tools focused on evaluation and life cycle perspectives. From their suggestions, the eco design tools have considered other significant factors outside environmental issues such as cost, service, social aspects, etc. To achieve a reliable analysis of the results, they suggested combining a number of eco design tools that allow a multi-criteria viewpoint when applying evaluation and analysing methods (Bovea and Perez-Belis, 2012).

Tool	Presentation
Analysis tools ABC-Analysis (Tischner et al. based on Lehmann)	<p>Purpose: This tool can be used for assessment of environmental impacts of a product. The product is evaluated on 11 different criteria and classified in one of the following grades: AZproblematic, action required, BZmedium, to be observed and improved, CZharmless, no action required.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: concrete</p>
The Environmentally Responsible Product Assessment Matrix (ERPA) (Graedel and Allenby)	<p>Purpose: The matrix is used to estimate a product's potential for improvements in environmental performance. Each life cycle stage (pre-manufacturing, product manufacture, product delivery, product use, refurbishment/recycling/disposal) is evaluated on five criteria (material choice, energy use, solid residues, liquid residues, gaseous residues).</p> <p>The environmental impact for each of the life cycle stages is estimated by grading each criterion from 0 (highest impact) to 4 (lowest impact).</p> <p>Checklists are developed to grade the criteria.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: The tool generates a quantitative result (from 0 to 100). But no quantitative data are needed to perform the grading.</p> <p>General or concrete prescriptions: concrete</p>

MECO (Wenzel et al., Pommer et al.)	<p>Purpose: An estimation of the environmental impact for each life cycle stage (material supply, manufacture, use, disposal and transport) is made by estimations and calculations of the amounts of materials, energy and chemicals. Materials and energy are calculated as consumption of resources. Environmental impacts that do not fit into the other categories should be included in the category 'Other'.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: Quantitative data are needed to perform the assessment. Some parts of the results are qualitative and some parts are quantitative.</p> <p>General or concrete prescriptions: concrete</p>
MET-Matrix (Brezet and van Hemel)	<p>Purpose: The purpose of the tool is to find the most important environmental problems during the life cycle of a product, which can be used to define different strategies for improvement. The environmental problems should be classified into the categories Material cycle (M), Energy use (E), Toxic emissions (T).</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: The results and data can be both qualitative and quantitative.</p> <p>General or concrete prescriptions: general</p>
Comparing tools Philips Fast Five Awareness (Meinders)	<p>Purpose: The tool is used to judge and compare different product concepts towards a reference product. Five criteria are chosen: energy, recyclability, hazardous waste content, durability/ reparability/preciousness, alternative ways to provide service.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: concrete</p>
Funktionkosten (Schmidt-Bleek)	<p>Purpose: The Funktionkosten tool identifies cost-effective product alternatives to be developed or can be used as an estimation of cost changes as a result of an implementation of an ecological design principle. General product functions are described and for each function a cost is calculated for each alternative solution.</p> <p>Life cycle perspective: no</p> <p>Qualitative or quantitative approach: quantitative</p> <p>General or concrete prescriptions: general</p>
Dominance Matrix or Paired Comparison (Tischner et al.)	<p>Purpose: The purpose of the tool is to set up a ranking of competing criteria or solutions, e.g. competing demands on a product or competing ecological requirements, by doing a systematic comparison between the different alternatives. Each individual alternative is compared qualitatively with all other alternatives.</p> <p>Life cycle perspective: no</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: general</p>
EcoDesign Checklist (Tischner et al.)	<p>Purpose: The checklist helps to identify the main environmental problems along a product's life cycle. The user has to evaluate whether the solutions in the checklist are good, indifferent, bad or irrelevant.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: concrete</p>
Econcept Spiderweb (Tischner et al.)	<p>Purpose: Econcept Spiderweb can be used for an estimation to decide between design alternatives. The user defines an appropriate set of criteria to be used for the estimation. For each solution a qualitative evaluation of the criteria is made and gives an environmental profile for each solution.</p> <p>Life cycle perspective: no</p> <p>Qualitative or quantitative approach: qualitative</p>

	General or concrete prescriptions: general
Environmental Objectives Deployment (EOD) (Karlsson)	<p>Purpose: The purpose of the tool is to present the relationships between the 'product's technical description' (e.g. material, reparability, energy efficient) and the 'environmental considerations' (material usage, reduce weight, use recyclable materials). The environmental considerations are weighted and this is specified by the user.</p> <p>Life cycle perspective: no</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: general</p>
LiDS-wheel (Brezet and van Hemel)	<p>Purpose: A tool to give an overview of environmental improvement potential to the designer. Eight environmental improvement strategies are utilized in the tool; selection of low-impact materials, reduction of material usage, optimisation of production techniques, optimisation of distribution system, reduction of impact during use, optimisation of initial lifetime, optimisation of end-of-life system and new concept development. Data from a reference product are entered into the diagram and according to the eight strategies; improvement options for the product should be identified.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: concrete</p>
The Morphological Box (Brezet and van Hemel)	<p>Purpose: This is not considered to be a typical Ecodesign tool but can be useful in finding creative solutions. The existing solution is broken down into elements, e.g. product parts. For each element different proposals are described. Then alternative solutions for the product are created by combining the proposals for each element.</p> <p>Life cycle perspective: no</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: general</p>
Prescribing tools Strategy List (Tischner et al.)	<p>Purpose: The tool can be used to improve the environmental performance of a product concept or to compare different product concepts. The tool consists of a list of suggestions for each life cycle phase (product manufacture, product use, product recycling, product disposal, distribution) to improve the environmental performance. The suggestions are based on the criteria: optimize material input, optimize energy use, reduce amount of land use, increase service potential, reduce pollutants, reduce waste, reduce emissions, reduce health and environmental risks.</p> <p>Life cycle perspective: yes</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: concrete</p>
Ten Golden Rules (Luttrupp and Karlsson)	<p>Purpose: The 10 Golden Rules is a summary of many guidelines that can be found in company guidelines and in handbooks of different origins. Before it can be used as a tool in a company, it should be transformed and customized to the particular company and its products. The tool can then be used to improve the environmental performance of a product concept or to compare different product concepts.</p> <p>Life cycle perspective: no</p> <p>Qualitative or quantitative approach: qualitative</p> <p>General or concrete prescriptions: concrete</p>
Volvo's Black List, Volvo's Grey List, Volvo's White List (Nordkil)	<p>Purpose: The purpose is to list chemical substances which must not be used (black list), should be limited in use (grey list) in Volvo's production processes, or chemical substances which may be critical from a health and environmental point of view (white list). The white list also suggests alternatives which, according to experiences and assessments made at Volvo, are potentially less hazardous. Life cycle perspective: no</p>

	Qualitative or quantitative approach: qualitative
	General or concrete prescriptions: concrete

Table 3.1 Fifteen Eco design tools described and assessed on the basis of the purpose of the tools (Byggeth, Hochschorner, 2006)

LiDS wheel (Brezet and van Hemel) in other name is Eco Strategy wheel applied in this research. The reason of selected of this tool were that i) this tool provides comparable data visually, ii) verified the effectiveness in the Korea Ministry of Knowledge and Economy within the several environmental preservation projects, iii) has higher acceptability than companies tools, and iv) smaller stress for learning by intuitional approaches.

Compatibility, which is the appropriateness of eco design tools into particular product development processes and eco design techniques with design process is also studied by Knight and Jenkins (2009). The report refers to the classification of eco design tools for the selection of the most appropriate methods for applying these tools to particular products.

In 2010, Ilgin and Gupta presented a comprehensive classification, which related to large scale environmental manufacture and product repair. This report introduced two different approached; an isolated way for evaluating the environmental issues and integrating these environmental impacts into the design processes for satisfying other traditional requirements. The results were assessed within six areas, which allows a taxonomy to be defined and categorised for the purpose of providing guidelines for selecting appropriate methods for designers.

Lofthouse, (2006) and her paper “Eco Design tools for Designers: Defining the Requirements” presents a new eco design tool ‘Information/Inspiration’, and asserted that initial Eco Design tools were made for industrial designers.

This paper has two parts; one explaining traditional informative perspectives and the other is more focused on innovative visualisation and descriptions of eco products and eco solutions. According to this paper the influences of eco design within a

holistic perspective gives direct impact to the supply chain which included product ownership, product returns and industrial ecology to influence environmental management and many other topical areas. Eco Design needs to consider all interactions within the way organisations manage their supply chains.

In conclusion, most eco design tools have been developed by engineers, marketers, strategists, manufacturers and other area experts, excepting designers; therefore, there are not many tools that understand the industrial design process or the cultural differentiations. Due to this, industrial designers face difficulties using eco design processes. Defining the perspectives of eco design tools shown in this chapter, eco design tools have to integrate with other areas to provide usable data for design. This means the necessity for developing eco design tools for designers and also creating communication methods between design and other areas.

3.2.1.1 Definition of different sustainability methods

- Eco design tools for generating design concepts

Since developing the concept of environmentally friendly design, it has been called various names such as eco design, sustainable design, green design and bio design etc. These design areas have been developed and segmented considering integration to technologies, economic benefit and extending environmental friendly design area. Particularly, environmental technologies development influenced to invent eco friendly materials to reduce environmental impacts and increase the rate of recycling. This aspect is a major concepts of these design approaches as design criteria largely emerged from the material properties of design (Fry, 2008).

Materials are a significant part of products, and the impact that they have on the environment is mainly determined during the design process. According to former pioneers' opinions, designing products with ecology in mind offers high potential to overcome environmental crisis and contribute to a more sustainable society (Papanek, 1995).

To reduce the environmental impacts using appropriate product design, various 'eco

design' strategies can be followed. Brezet and Van Hemel (1997) offer a categorisation of eco design strategies in seven main strategies and twenty nine sub strategies, listed in Table 3.1 overleaf.

	Strategy	Sub-Strategies
	New concept development	Dematerialisation, shared use of product, integration of functions, Functional optimisation of product components
Product component level		
1	Selection of low impact material	Cleaner material, renewable material, lower energy content material, recycled material, recyclable materials
2	Reduction of material usage	Reduction in weight, reduction in transport volume
Product structure level		
3	Optimisation of product techniques	Alternative production techniques, fewer production steps, lower/cleaner energy consumption during production, less production waste, fewer/cleaner production consumable
4	Optimisation of distribution system	Less/cleaner/reusable packaging, energy-efficient transport mode, energy-efficient logistics
5	Reduction of impact during use	Lower energy consumption during use, cleaner energy source, fewer consumables needed, cleaner consumables, no waste of energy/consumables
Product system level		
6	Optimisation of initial lifetime	Reliability and durability, easier maintenance and repair, modular product structure, classic design, strong product-user relation
7	Optimisation of end-of-life system	Reuse of product, remanufacturing/refurbishing, recycling of materials, safer incineration

Table 3.2 Eco design strategies (Brezet and Van Hemel, 1997)

In this table, the major strategies can be distinguished by optimisation and reduction approaches. The biggest influence on all products, including the environmental impacts, started at the beginning of the product development process (Giudice et al., 2006). Therefore, it may be appropriate progressive approach, when eco design strategies are thoroughly considered at the beginning of the development process (Tischner et al., 2000).

Some eco design strategies, particularly the strategy 'new concept development', are impossible to implement at a late a phase of the product development process. Roozenburg and Eekels (1995) as well as Melgin (1991) suggested that the product development process could be divided into two main stages:

1) A product planning or product concept phase, which clarifies the main idea that will be developed, and the drivers for doing so, and.

2) A strict development phase, which provides a plan for actually making the product.

Consequently it is important for eco design to be practiced at both the product planning and the strict development phase, however a more important issue is the designer needs for the appropriate tool to understand the features and advantages of each tool and use (Behrisch et al, 2010).

Another definition, for eco strategies which follows is based on three different organisational categorisations.

The eco design methods follow five eco design strategies and each design tool supports each strategy or connects with other tools for attaining more systematic results (An and Cho, 2006).

Several Korean organisations within the Korean government and related to environmental preservation of international organisations have surveyed and reported the understanding of which tools can be used in recent eco product development. Major organisations were the Korean Ministry of the Environment, UNEP (United Nations Environment Program) and WBCSD (World Council for Sustainable Development) who joined in this survey.

These three organisations gave highly ecological impacts to the Korean industries and markets, for example; the Korean Ministry of Environment established a task force team for forecasting and making new eco strategies to deal with the rapidly shifting international environmental policy. Furthermore, these strategies were based on the background for a whitepaper or new national environmental policy.

Korea Ministry of Environment	UNEP (Brezet)	WBCSD
<ul style="list-style-type: none"> ■ Recycling Possibility improvement ■ Toxic Substance Reduction ■ Energy efficiency improvement ■ Amount of material reduction ■ Emission material reduction ■ Product lifespan optimization 	<ul style="list-style-type: none"> ■ Selecting smaller environment impact material ■ Reducing amount of using material ■ Optimizing production technology ■ Reducing environmental impact during usage ■ Extending product lifespan ■ Optimizing disposal process 	<ul style="list-style-type: none"> ■ Reducing amount of using material ■ Reducing amount of using energy ■ Reducing emission of toxic material ■ Improving rate of recycling material ■ Using recycling material ■ Extending product lifespan ■ Reinforcing product function

Figure 3.5 Eco product strategy approaches in different organisations

(The National Cleaner Production Centres (NCPC), (2004))

The above figure describes major eco strategies from different organisations. Their strategies focus on different perspectives because of the size or the main targets of the organisation, which differ as well as having major serious problems for the environment.

Environmentalists and ecological experts in NGO have asserted that different cultural differentiations such as the Korean ministry of Environment is more focused on production levels rather than usage and recycling because they think that providers or manufactures care about material usage levels as their main responsibility. Also, the Korean eco policy is more concerned with material treatments such as toxicity and CO₂ emission compared to eco management or re-considering manufacturing processes. Compared to the Korean Ministry of Environment, UNEP's strategy is more focused on usage and disposal levels because they think many initial national policies started from reducing toxicities and pollutions in production levels therefore using alternative fuel or increasing reuse percentage will be the next steps (McAloone, 2004).

World Business Council for Sustainable Development: WBCSD is focused on efficiency, which means consideration regarding reduction of material and restructuring manufacturing process. However these different perspective strategies have the same broad purpose and only the detail in the approaches can distinguish them

Each strategy has different advantages, however all the strategies purpose 'Extending product lifespan' or 'Find solutions to produce environmental benefits socially and economically'.

Many current eco designers have designed eco products using only traditional product design strategies. These generally use design and product housing components or packaging for the products, which use traditional product design approaches (McAloone, 2004).

Some engineers have adopted eco design methods to develop their own products, however if these previous eco products only fulfil one environmental aspect and give impact to the environment directly or indirectly, then how can we conclude those are eco products (Jung Woo An, et. el 2005).

It is difficult to ensure that these strategies succeed in developing eco products. However, those strategies may help to consider ecologically and creatively and also provide guidelines to maintain balancing eco product and designed goods in 'TBL theory' and 'Cradle to Cradle' perspectives.

This chapter explains the relationship between eco-friendly product development methods, eco-friendly strategies and sub-strategies, and structures selected by major eco organisations.

The orange colours marked in figure 3.5 illustrate eco design methods, which will apply to the student experience for the pilot study and LCA evaluation for the mobile phone development for this research. This research mostly applies to eco methods and interested major international and Korean organisations, except for a few methods related to energy consumption and using new environmental technologies. However the gap for applying eco methods between this research and organisations shows a different focus, how they are used and who uses them because this research is focused on designer's perspectives.

The Korean professional eco engineering book (An and Cho, 2006) introduces guidelines for eco strategies. To develop new products, the development strategy is required prior to using the methodology. The following strategies show recent eco design trends which the researchers asserted. i) Strategies for products without shape or form, ii) Increasing common use and iii) Providing service. The strategies show 'intangibly' is the key to recent trends. In the past, solutions dealing with customer needs were from functionality or the configuration of products (An and Cho, 2006). However, the new solution is for the content, which interacts between relationships for services and functionality of products (Korea Environmental Industry & Technology Institute, 2005).

Therefore, this thesis also research production stages, usage, disposal, and recycling. What is more, this thesis will verify the relationships and validity of objects through a design methodology, ecological process of analysing, mobile phone user environmental analysis, contract analysis and LCA.

3.2.1.1.1 Standards for selecting eco design strategies

This paragraph demonstrates the strategies in colours (figure 3.5), which will be the target for further pilot studies and major objects for ecological evaluating in this research. These marks demonstrate the 8 eco design methods will apply to this research and these eco design methods and marks illustrates different significance and contexts by national, regional and international organisation standards and current circumstances.

The purpose of this research is 'finding and understanding eco design methods in different values between environmental and business perspectives; therefore the author considers the appropriateness, which have to be related to general industrial design process and creates similar outcomes for the designers. However, it may need to apply engineering and marketing eco methods to industrial designers to gain more variable data in future research.

To establish, the author compared eco design strategies to traditional industrial design methods.

As a general rule, an industrial design consists of:

- Three-dimensional features, such as the shape of a product,
- Two-dimensional features, such as ornamentation, patterns, lines or colour of a product; or
- A combination of one or more such features (World Intellectual Property Organization, 2006)

Looking other references, industrial design has three key factors that embrace 'understanding principles of shape', 'applying logical colour and pattern' and 'considering manufacturing process' (Sung Soo Hong 2007).

- Understanding principles of shape – industrial designers should understand purpose of objects to apply and to generate ideas and shapes and also designer should have the logical background for these designing.
- Applying logical colour and pattern – the colours and patterns, which are applied to the product designing should have logical reasons and those should be corresponded with object's purpose.
- Considering manufacturing process – if the industrial designer designed without considering production (mass production) it only creates imaginary design results, hence design results should be based on productivities and marketability in the industrial design (Sung Soo Hong 2007).

To undertake this research, the author established selection standards is based on traditional industrial design features and principles.

On the other hand, the eco design methods, which are use in this research, should generate comparable ecological design outcomes with different business perspectives such as design, marketing and engineering, and also require comparison with different roles positions that CEOs, designers and operators.

Although several eco design methodologies are focused on environmental friendly technologies and systems generate comparable outcomes. However, these methods may only use engineering approaches rather than design perspectives. Hence, eco methods selection could be applied in the same conditions and only add or reduce the points in different features of eco design methods.

To evaluate eco design methods, the author will apply the Eco design strategy wheel is qualitative analyzing method to estimate appropriateness for the research.

This research has established standards to select eco design methods through those factors.

No	Categories	Contexts
1	Familiarities with traditional industrial design	<ul style="list-style-type: none"> • More focused on structure & shape of product housing and materials rather than applied systems and technologies. • Minimum required environmental friendly engineering and technologies knowledge to generate design results. • The results have to be created by eco design methods rather than using alternative technologies or systems • The results could be reflected and considered current manufacturing capabilities and process
2	Appropriateness of Comparable methods	<ul style="list-style-type: none"> • The results need to be comparable in different area that design, engineering and marketing • Each eco design tool demonstrates differentiations advantages and disadvantages
3	Considering participant design abilities	<ul style="list-style-type: none"> • Considering further pilot studies in this research, the eco methods have to be understandable
4	Distinguished eco design methods	<ul style="list-style-type: none"> • Grouping eco design methods by product lifespan and different approaches (see section 3.2.4) and selecting the representative eco design tool within the group
5	Qualitative analysis by Eco strategy wheel	<ul style="list-style-type: none"> • Using Eco strategy wheel, which is for visualized evaluating effectiveness (see section 3.2.1.1.1)

Table 3.3 Standards for selecting the eco design tools in the research (Identified by Nowosielski, et al, 2007)

Selecting eco design tools via categorised tools by considered standardisation was a significant step for undertaking effective experiments and evaluations. Generally, the Eco design strategy wheel applies to analysis of eco design tools; however it was not used in this research due to various limitations such as students' design and learning abilities, cost, time and also the researcher's capability.

This research expected several conditions for eco design tools. Each tool has to show obvious functional, emotional structural and technological features for making comparable results in qualitative and quantitative evaluations.

The eight eco design tools were chosen from twenty four for this analysis, were based on four main criteria and each category has several sub categories (Identified by Nowosielski, et al, 2007).

> It must be product oriented;

- Avoid eco tools that are focused on national and international eco systems or necessitate changing consumer behaviour and moralities
- Avoid eco tools that influence cultural differentiations and peoples' awareness of green issues

> It must be intended for primary use by a designer

- Avoid the highest eco technologies, which can be an ecological panacea
- Avoid too complicated or expert dependant resource demand tools

> It must have sufficient literature available for understanding

- Chosen the tools for creating obvious design results
- Chosen tools that have clear subjects in the design perspective

> It must be accessible.

- Chosen tools for teaching and learning for designers

The full version of some eco design tools particularly quantitative evaluations were unattainable due to heavy cost and expertise knowledge demands, therefore simplified evaluation versions or demos were used instead. These criteria were intentionally broad in order to achieve a wide range of scopes to be evaluated.

In this research, eight eco design tools, selected through the above wide range of selecting standards combined with the eco strategy wheel to find the appropriate tools for the experiments. The aim of the Eco Design strategy wheel is to visualise the strategies that can be followed for Eco Design.

The Eco Design strategy wheel considers eight eco design strategies:

i) New concept development, ii) Selection of low-impact materials, iii) Reduction of materials usage, iv) Optimisation of production techniques, v) Optimisation of distribution system, vi) Reduction of impact during use, vii) Optimisation of initial lifetime and viii) Optimisation of end-of-life system.

Mostly eco design strategies relate to the product lifecycle. The initial strategy is different, since it relates to a much more innovative strategy than the others. Some strategies relate to the product component level, some to product structure level and others to the product system level.

During the analysis of the environmental product profile, various improvement options came up spontaneously. The options for improvement will be the result of applying the MET matrix and the Eco Design checklist. However instead of those qualitative evaluation tools this research used a simplified matrix, which was developed for this experiment.

New concept development
@ New concept development - Dematerialisation - Shared use of the product - Integrations of functions - Functional optimisation of product

Product Component Level
1. Selection of low-impact materials - Cleaner materials - Renewable materials - Lower energy content materials - Recycled materials - Recyclable materials
2. Reduction of materials usage - Reduction in weight - Reduction in (transport) volume
Product Structure Level
3. Optimisation of production techniques - Alternative production techniques - Fewer production steps - Lower/cleaner energy consumption - Less production waste - Fewer/cleaner production consumables
4. Optimisation of distribution system - Less/ cleaner/ reusable packaging - Energy-efficient transport mode - Energy-efficient logistics
5. Reduction of impact during use - Lower energy consumption - Cleaner energy source - Fewer consumables needed - Cleaner consumables - No waste of energy/consumables

Product System Level
6. Optimisation of initial lifetime - Reliability and durability - Easier maintenance and repair - Modular product structure - Classic design - Strong product-user relation
7. Optimisation of end-of-life system - Reuse of product - Remanufacturing/refurbishing - Recycling of materials - Safer incineration

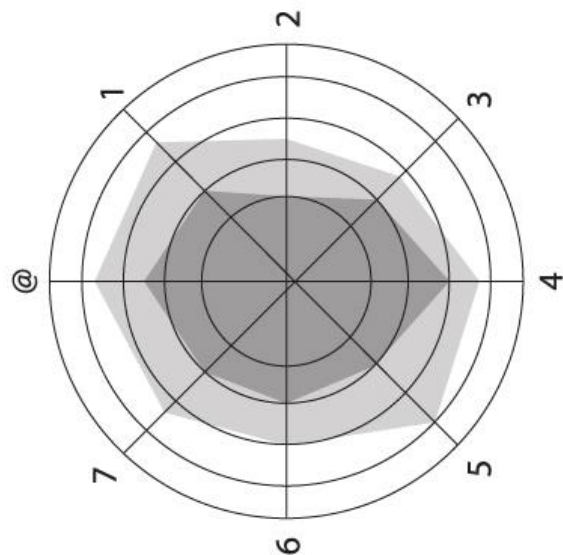


Figure 3.6 The Eco design strategy wheel (Brezet and Van Hemel, 1997)

According to Brezet and Van Hemel (1997), to generate more improvement options, the object can also go the other way around by using the Eco design strategy wheel as an option-generation tool. This method (Eco design strategy wheel) is only for evaluating effectiveness of eco design methods therefore this has differentiations with eco design evaluation method, which is for evaluating eco design method. In hence, this method applied to find and illustrate the different and identified contexts of eco design methods in this research but this method cannot analyse the market research and product analysis.

The establishment of eco design priorities can be drawn up and visualised by adding two activity lines to the Eco design strategy wheel: short term activities versus long-term activities however those two lines will be used to show comparison of the results of design issues versus other issues.

In the case of the Eco design strategy wheel, it has been verified in undertaking several Korean government environmental projects such as ‘developing business of environmental friendly design strategies’ and ‘developing eco design roadmap’ in Korea Institute of Industrial Technology Evaluation and Planning and Korean Ministry of Knowledge Economy. The strongest feature of this tool is that it compares different methods visually.

3.2.1.2 Classified Eco design methods

3.2.1.2.1 Extending product lifespan - Strategy of Physical Optimisation

Figure 3.3 demonstrates the relationship between various key eco strategies, which are used in engineering areas and create sub-strategies, which support key strategies and various eco methods, used for product realisation.

The first strategy is ‘the Optimise Eco strategy’ and the context of this supports the improvement of ecologically physical optimisation, to reduce environment impact.

The second strategy is ‘the Optimise material use’ and it is focused on materials selection and processes (NCPC report 2008). This strategy is a very similar concept to current industrial design trends such as Colour, Material and Finishing (CMF) (Jung Woo An, et. el 2005).

The third strategy is ‘Optimise production techniques’ and it focuses on production process (NCPC report 2008). These methods may help to reduce toxicity emissions and increase manufacturing efficiency through simplification of processes and applying new manufacturing technologies (Jung Woo An, et. el 2005).

The fourth strategy is ‘Reducing impact during use’. This strategy focuses on the quantitative amounts of various material emissions and attempts a variety of ways to reduce toxicity emissions and control energy consumption, which can reduce the environmental impact (NCPC report 2008). To undertake the designers’ strategy, they have to understand the definitions of technologies related to energy consumption and establish multidisciplinary teams to achieve effective realisation.

The fifth strategy is ‘Optimising end-of life system’ and is for maximising results during reuse and recycling. This strategy can have an impact in simplifying manufacturing processes and reducing material for the packaging design, however this also influences people’s awareness and government recycling systems.

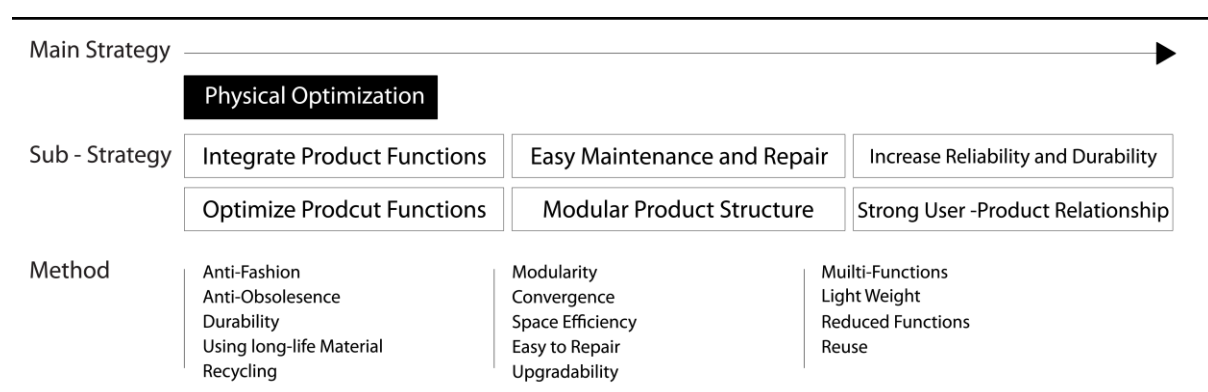


Figure 3.7 Eco product strategy and methods: Physical Optimisation (NCPC report 2008)

This approach has been used broadly to develop eco product in engineering and its major objective is to extend the product lifespan as long as possible. To achieve

eco products through this approach requires several conditions; firstly, material consumption has to be reduced or the amount of toxic emissions. It means the designer / creator has to consider eco standards to achieve longer product lifespan without reviewing the environment, if only product lifespan is extended, this would not necessarily mean there was an environmentally friendly product developed. Secondly they need to study the user's reflection; particularly anti-fashion and anti-obsolescence. These methods approach emotional issues therefore producers have to react to consumer and market reflections very sensitively (Korea Environmental Industry & Technology Institute, 2005).

Thirdly, producers have to think of energy efficiency. Many eco products have been named by providers but are not much different to normal goods. They have not considered eco efficiency enough, especially durability or long life span products, are unmanageable, and heavier and thicker than they should be.

The strategy of Physical Optimisation is applied from a very early stage in the production process and it is used for most product forms in the engineering field (An and Cho, 2006). This feature can be considered in qualitative and quantitative approaches as both means can achieve this; the creator has to consider several sub-strategies, which have very different concepts and perspectives and there needs to be integration between each tool.

This strategy may enhance product capacity physically which is related to collateral benefits from environmental product improvement and extending the product lifespan ecologically. It starts to consider the impact at a planning level for realisation of product's housing shapes and creating new structures for inside the housing to decrease a user's ecological impact (McAloone, 2004).

Anti-Fashion, Durability, Recycling and Upgradability applied to the research exercise.

3.2.1.2.2 Applying less eco impact material

- Strategy for Optimising Material Use

Figure 3.4, all approaches for eco design can impact on all functions of product and the product's physical ecological improvement may influence the emotional satisfaction. Jung Woo An's study found during the several tests and evaluations, emotional approaches such as Anti-fashion require sophisticated design performance; however it needs enormous marketing investment and creative innovation (Jung Woo An, et. al 2005).

To sum up, undertaking the optimisation strategy, needs fulfillment of multiple aspects; emotional, functional and structural perspectives and each area can have various impacts directly on the environment, on the other hand, if a designer lowered one single aspect then it may give higher eco impacts than traditional goods.

The major focus of this is not just to change product lifespan, but to consider changing the system and increasing market awareness.

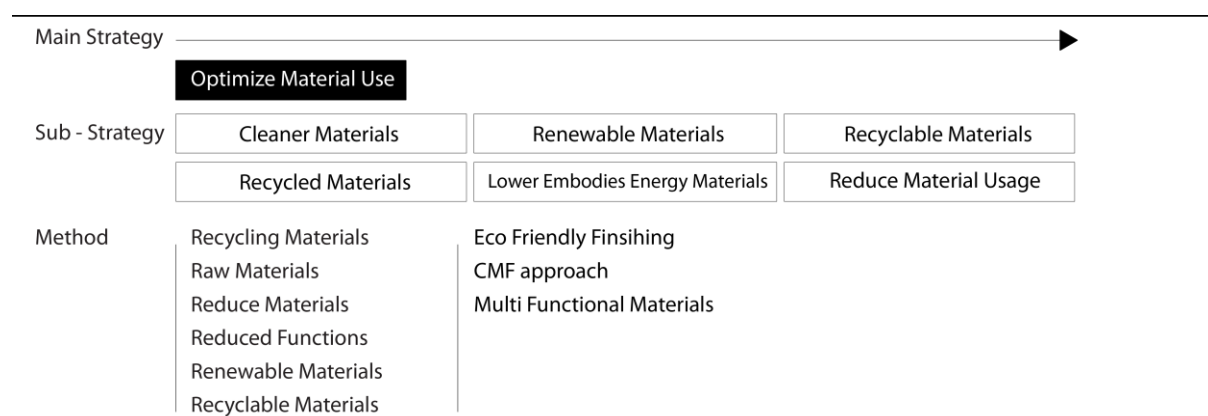


Figure 3.8 Eco product strategy and methods: Optimise Material Use (NCPC report 2008)

Material toxicity can directly impact the environment, therefore selecting or finding less eco impact materials has been a very significant factor in deciding eco product status. Material effectiveness may occur in every product lifespan through production, usage, disposal and recycling. Selecting materials can also decide the possibility of recycling or reusing and to accomplish this, it needs to fulfil different stages of recycling or reusability such as collecting, smelting, manufacturing and transportation (Korea Environmental Industry & Technology Institute, 2005).

Furthermore, a consumer's ecological concerns have recently increased and influenced health care trends, created a variety of social trends such as Lifestyle of Health And Sustainability (LoHAS) and Well-being and those different issues have combined with environmental and health care issues. These social aspects provide fundamental reasons for people to pay more for the environmental products and build bridges between eco product development and social demand (Jung Woo An, et. al 2005).

These social concerns and international ecological pressures have occurred due to various recyclable product developments and national recycling systems and also undergone the optimisation strategy discussed earlier, also tried in many NGOs (particularly designers' groups or ecological sellers) and ecologically advanced countries.

Optimising Material Usage uses several significant decisions at different levels i) the planning level, which decides what material to use and how to use it, ii) production and disposal levels: which comes at the beginning of the results and iii) the recycling level, which shows how many components and what percentage can be recycled or reused.

The planning level needs to find more eco friendly materials than currently exist and should consider ways to apply new eco materials. It also needs to think of shipping distances and reducing fuel consumption. The production and disposal level demand product quality control (QC) because innovative new materials could not often achieve the market standards and also needs to evaluate the types and amounts of material emissions. Designers need knowledge about new ecological materials to increase recycling or reuse of products. Since the development of the recycling concept, many engineers and material experts have designed recyclable products but these products mostly failed because they approached functionality therefore increasing the designer's capability, especially the understanding of new materials, which has been a more significant factor in the development of recyclable products.

The strategy for optimising Material Use can be split into two phrases; i) to establish innovative eco materials such as PLA and Natural Plastic which may increase

recycling percentages and ii) the application of multi-functional materials such as colour changing materials and double side pattern to decrease errors; this may impact the total amount of material and energy consumption.

In this research, reduction of Materials, reducing Functionality and material recycling were used in the experiment.

Since the Millennium, design language has faced a turning point that has seen a more simplified shape but achieving obvious visualised identities against a product that has become more complex and intelligent. Currently CMF has been the key design language by increasing material technologies and inventing intelligent patterns and paints, such is the design trend shifting and the material optimisation use strategy is a similar concept to the CMF approach. Objects using both concepts increase the product design value by applying new materials.

To sum up, CMF has not only been a significant development in the product design area but also in the eco design area. The distinguishing factors between those are i) CMF or eco materials are more focused on reducing environmental impacts rather than emotional values, ii) some eco design methods under this strategy have similar concepts to traditional product design approaches, iii) to achieve and maximise ecological results via this strategy, designers have to understand material and manufacturing process knowledge and also need to cooperate better with other departments (Jung Woo An, et. al 2005).

3.2.1.2.3 Approaching by environmental high technologies

- Strategy to Optimise Production Techniques

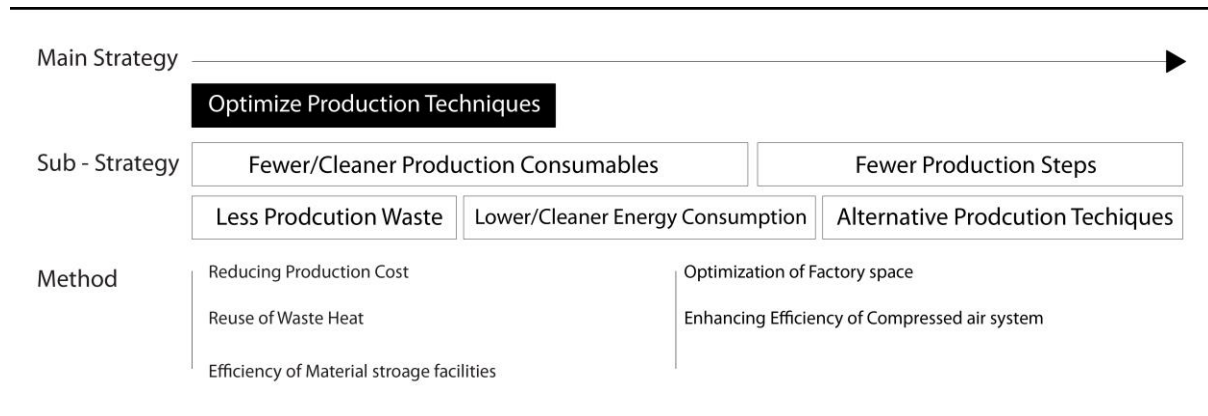


Figure 3.9 Eco product strategy and methods: Optimize Production Techniques (NCPC report 2008).

According NCPC report (2008), many of product users especially electronic product users answered 'yes' in 'do you use the most product functions?' however the major problem in this question is mostly users even do not know the product functions perfectly. The context of this strategy is started from the concept that if product has only core functions by checklist or priority of functions then it will address reducing production cost and saving battery lifespan.

The objective of Optimising a Production Techniques strategy is to increase product manufacturing efficiency as well as reducing hazardous material emissions for the health and environment through the innovation of new eco technologies whilst considering and managing the production processes.

As people's concerns rapidly grow regarding the environment, clean production technology has been the most significant national business and has shown successful results, particularly in the car industry for reducing environmental pollution within the manufacturing process. In Korea, President Park's new government (2013) announced five key future industries and the clean production and management industry is part of the first ranking.

In the past, clean production meant only focussing on decreasing pollutants, especially water pollutions, rather than considering manufacturing efficiency.

However, using various international eco regulations, particularly the Kyoto Protocol, which directly impacts amounts of CO₂ emission during the entire product lifespan, therefore using clean production technology. Currently improvements of the ecological manufacturing process achieved multiple objectives that have not only reduced pollutants but manage the economic benefit by increasing manufacturing efficiency, saving operation time, consolidating eco regulations and supporting tax.

This strategy could influence ISO 14001. Although ISO 14001 is not enforced, it has stimulated corporations to apply clean production. The strategy has not been adopted in this research because the methods are mostly focused on re-considering manufacturing systems by adopting new high technology systems and demand professional engineering knowledge re the production process rather than the design area.

3.2.1.2.4 Decreasing environmental impacts by systematic approaches

- Strategy to reduce impacts during use

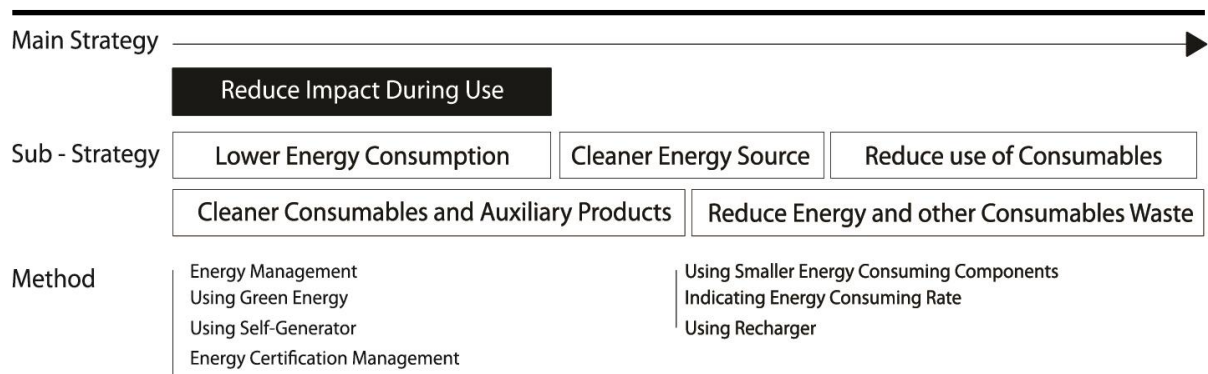


Figure 3.10 Eco product strategy and methods: Reduced Impact During Use (NCPC report 2008)

General electric products have demanded various types of energies in their lifetime; however, much energy consumption has also been wasted without using the product - 10% of energy is consumed on standby power per family globally – (<http://standby.lbl.gov> Access date: 2nd April. 2013, Harvard).

The period of usage particularly the mobile phone can be defined into four key areas; usage, standby, repairing and charging. Most eco design methods in the 'Reduce Impact During Use' strategy are related to using, standby and charging because the methods are implementing physical optimisation for repairing or maintaining and also changing component shapes and considering new ways to assemble which can be more related to physical optimisation.

To achieve this strategy, the designer has to consider how to improve the consumer's awareness re the environmental preservation and needs to find key facts to reflect in the design. Major concepts of 'Reduce Impact during Use' not only applies new ecological technologies but also focuses on consumer behaviours, which can continually increase energy efficiency during usage, i.e. the target of this approach is to analyse a user's products using behaviour rather than looking at the manufacturers' responsibilities.

A comparison of these methods with other strategies where tools are more focused on the quantitative results, such as certifying standardisation and measuring data from energy efficacy, calculating these results and indicators may stimulate consumer's consumption behaviours and decisions. However other tools are more focused on production and disposal levels, the first method targets different perspectives; secondly these methods consider social awareness rather than product responsibility and thirdly these methods can be used in political and commercial ways by NGO (CNRC, <http://dfe-sce.nrc-cnrc.gc.ca/000>, Access data: 10th March. 2013 – Harvard!).

In summary, the product development methods for the design builds the structure and shape for realising the ideas for the goods, however many resources and innovations are very abstract. Often it cannot estimate market impacts or consumer's potential fulfilments quantitatively before mass-production or launching the new products; however these approaches may help to estimate how and what consumers need and also provide the invisible potential market expectations.

3.2.1.2.5 Considering End-of Life system

- Strategy to Optimise End-of-Life System

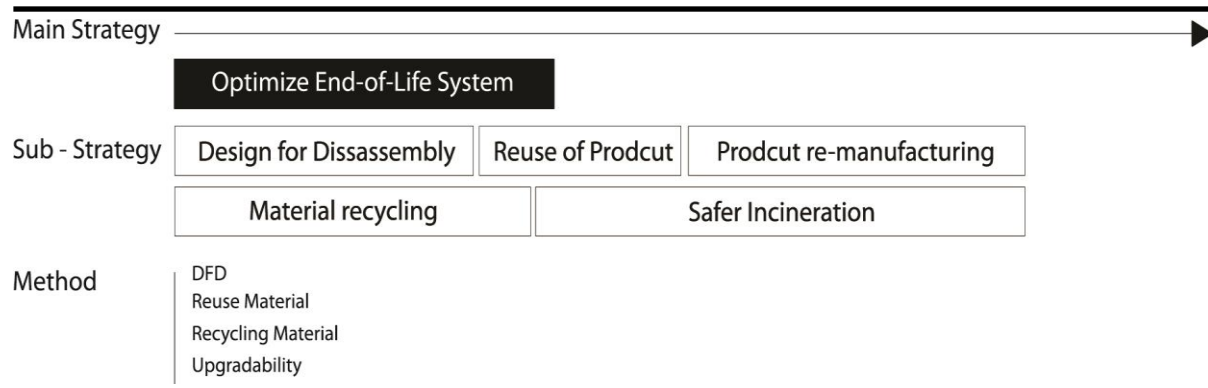


Figure 3.11 Eco product strategy and methods: Reduce Impact During Use (NCPC report 2008)

The 'Optimise end-of-life' system can be a similar concept to 'Cradle to Cradle' (McDonough and Braungart, 2002) and the major context is to increase recycling and reusing percentages and manage industrial waste through designing the components, and shape structures and planning the manufacturing processes.

In addition to the various international eco regulations, which have emphasised manufacturer's responsibilities particularly industrial waste (WEEE) after using electrical products. The Korean government has also enforced EPR (Extended Producer Responsibility) from 2003 so manufacturers have to consider the recycling plan and product reuse from a very early stage of the product development.

Many countries have collecting systems for operating recycling because they recognised that recyclable material can be a significant resource. However, to undertake recycling and reuse, the system demands various stages within processes and investments. Consequently, establishing recycling or system reuse can achieve increasing social awareness and long-term ecologically systematic achievements.

Establishing recycling systems such as collecting, washing and selection of various eco methods can impact on rates of recycling.

The concept of Design for Disassembly (DfD), which has been applied to this research, considers disassembly of the product and disposal processes that can be reduced for the best options for increasing recycling rates.

DFD benefits provide: i) cost reduction during maintenance ii) cost reduction to stimulate reuse and recycling proportions iii) waste reduction to improve material recycling iv) help for product test analysis and v) contributes to eco regulations by stimulating product collection waste and improving the responsibility of producers.

To sum up, all of these methods cannot work without recycling facilities however each tool can directly impact and stimulate rates of recycling through product shape changes, more effective assembly and disassembly methods and planning for better disposal processes.

In conclusion, most eco design methods applied in this research involved eco strategies and perspectives of each strategy, were aimed to achieve different eco product development processes and product lifetimes. Therefore the research results point to realistic and comparable outcomes.

3.2.1.3 Eco design tools are used in the study

- **Design for Recyclability (Recycling Design)**

The aim of using recycled material can reduce raw material, energy and water consumption.

According to Thompson (1997), the use of recycled materials can reduce waste, raw material consumption, air and water pollution, and energy consumption. Graedel and Allenby (2003) suggested avoiding mixing materials in assemblies, as one of the important rules of design for recyclability.

For this reason, some eco advanced countries have a very logical recycling system at the collection level, for example, Japan has two different recycling bins, which are separately collected through differing plastics and Germany has three different coloured recycling bins and these collect different colour bottles.

Billatos and Basal (1997), support this, indicating that the number of different plastic and non-plastic materials used in a product should be minimised to enhance product recyclability.

- Design to Minimise Material Usage (Reduced material / Reduced functions)

Reducing the amount of material used over the product life cycle is an effective method of reducing environmental impacts (Otto and Wood, 2001). This strategy can be applied to three areas: i) reducing the product's physical dimensions, ii) weight reduction, and iii) using alternative materials such as carbon fibre reinforced polymers for car bodies (BMW, 2002). However to achieve this designers should have knowledge on materials before applying new materials because some materials give more environment impact when using smaller amounts.

- Design for Durability (Durability / Upgradability / Easy to repair)

Designing products to last longer reduces both resource use and waste generation. Upgradeability or modular design is a form of product life extension. However, in some cases, if impacts from the complete product lifecycle are considered, increasing durability may have an adverse effect by reducing the adoption of more environmentally beneficial technology with, for example, increased energy efficiency or emission controls (Lewis and Gertsakis, 2001).

- Design for Disassembly (DfD)

The purpose of DfD is to ensure that a product system can be disassembled at minimum cost and effort. Adopting DfD methods will contribute to quicker disassembly processes and recovering a larger proportion of the system components (Fiksel, 1996). However, to achieve Design for Disassembly it needs to consider product structure, joints, durability and assembling and disassembling processes.

- Design for Energy Efficiency (Energy Saving)

A major source of environmental impact is the energy consumed by a product during its use. This method has been a very important approach in car manufacturing and

electronic industries and enforced the Kyoto protocol, many of these types of manufacturing have to consider the efficiency of energy and emissions.

- Anti-fashion

The purpose of anti-fashion is to stimulate consumer's emotions to extend the consumer's fulfillment through design and marketing perspectives. This not only looks to modify shape or functionality but also needs to consider finding average user behaviours and market insight.

3.2.2 Eco evaluation tools for the products based on sustainability

This section shows eco evaluation tools for providing qualitative and quantitative data to support design and product development. Eco evaluation tools can be divided into qualitative and quantitative indicator and this research used LCA to analyse mobile phones, which are located in the quantitative area.

This evaluation tools below are categorised by purposes of use and types of expected result values and as descriptions of each tool, quantitative methods give higher reliability compared to qualitative indicators. However, most of these tools are unsuitable for designers. Contrary to this, qualitative methods accomplished simpler processes but have lower credibility and produce limited usable data.

This list shows name and simple descriptions of the qualitative evaluations method (Bovea and Perez-Belis, 2012).

- Checklist type of tools

AT and T (Keoleian et al, 1995), Kodak (Betz and Vogl, 1996) and Fast Five Philips (Meinders, 1997)

For undertaking product design processes and product design, this provides systematic material from a series of formulated questions.

- Matrix Element Checklist for ERP (Graedel and Allenby, 1996)

For decreasing the analyst's subjectivity when the ERP(Environmentally Responsible Product) is completed, the matrix uses a combination of questions. This can provide the data relationships between environmental issues and the product life cycle.

- MET-Matrix (Materials, Energy, Toxic emissions) (Brezet and van Hemel, 1997)

This method has two matrices, one of them is focused on the environmental concerns (materials cycle, energy use and toxic emission) and the product life cycle (production, use and disposal) stages. The other matrix evaluates the gaps between various effects (low, medium and high) instead of the life cycle stages.

The matrix provides structured qualitative data with implementable results and experiences and is based on the analyst's knowledge.

- Ten Golden Rules (Luttropp and Lagerstedt, 2006)

This tool establishes expertise of the integration from a wide range of authentic environmental requirements into the product development process. In summary, the tool has three major issues; i) ten rules can impact on the product development process, ii) easily modified for user's demands and iii) can improve the environmental performance in the product concept generation level or when comparing methods to different product concepts.

The eco evaluation tools below, which are called Semi-quantitative techniques have both characteristics (Bovea and Perez-Belis, 2012).

- Environmentally Responsible Product/Process Assessment Matrix (ERP) (Graedel and Allenby, 1996)

The matrix consists of two different parts, one for products and another for processes. The matrix establishes evaluation standards through environmental concerns and presents life cycle stages through this. The matrix gives points from 0 (highest impact and very negative record) to 4 (lowest impact and exemplary record).

- Environmental Product Life Cycle Matrix (EPLC) (Gertsakis, 1997)

This tool approaches the problem in a similar way to the ERP matrix, which distinguishes between processes and products. However instead of the environmental concerns, this considers relationships between product life cycle stages and different environmental impacts. This also points to its entries and the range is from 4 (highest impact on the environment) to 0 (lowest impact on the environment).

- Eco-Design Checklist Method (ECM) (Wimmer, 1999)

The feature of this method is that it combines checklists with semi-quantitative indicators. Two differing parts have different roles, checklists which are focused on the levels of product parts and functionality and concepts with semi-quantitative indicators consider the ecological requirements. The indicator gives a point of ecological impact rates (1.0 “requirements are fulfilled” to 4.0 “requirements are not fulfilled”).

- Streamlined Life Cycle Assessment (SLCA) (Bennett and Graedel, 2000)

This tool has particularly strong ability to compare the environmental impacts of different products. It can identify key issues and highlight major opportunities to achieve environmental improvements.

- Product Investigation, Learning and Optimisation Tool (PILOT) Wimmer et al. (2004)

The main improvements in PILOT compared to ECM are the increased number of eco design guidelines included, the different types of working approaches that can be able to be adopted to use for eco design and the detailed explanations provided for every single eco design guideline, provided in the form of a description and an example.

These tools are quantitative techniques. These methods outcomes give relatively accurate values and can apply to products, social and environmental systems and policies to evaluate environmental burdens.

- Environmental Indicators, Navinchandra (1991), Jasch (2000), Persson (2001)

These environmental parameters support alternative designs to be evaluated from an environmental perspective, hence facilitating the decision-making process during product development.

- Oil Point Method (OPM) Bey et al. (1999), Lenau and Bey (2001)

Indicators in the OPM are defined as the energy consumption or energy content measured in kilograms of crude oil (1 Oil Point [OP] energy content of 1 kg crude oil . 45 MJ).

- Life Cycle Assessment (LCA), ISO 14040-44 (2006)

Method that allows the environmental impacts associated with a product to be evaluated. It considers the entire life cycle of the product, encompassing the extraction and processing of raw materials, manufacturing, distribution, use, recycling and final disposal and allows the analyst access to environmental indicators obtained for each impact category or to obtain a single indicator grouping all the impact categories considered.

There are four reasons to select LCA in this research that i) resources for this research about LCA may be the most appropriate to collect compare to other methods, ii) to find the environmental experts who uses quantitative evaluate analysis method, LCA was the most common tools in this area, iii) this tool is identified the effectiveness and appropriateness by Korean government and large sized companies, and iv) comparing with other tools, LCA is equal to other quantitative methods.

3.2.3 Eco decoding tools for designers

To undertake design by using eco evaluated results, not many current industries can decode or implement eco quantitative evaluation results. As previous sections mention designers have generally used very abstract information and visualised

materials for their designs, thus they are not confident about using quantitative values. However some features of eco product developments, which have to reflect many markets demands and can deal with various international eco regulations need quantitative analysis, such as LCA.

Since designers and engineers recognized these requirements, the various solutions have come out. Decoding methods are one of general solutions and the purpose of this is translating from quantitative values to qualitative information. For example, this research adopted Eco-compass method for translating LCA results.

In summary, the eco design tools are distinguished by purpose and features of the eco ideation tool for generating ecological design concepts, the eco evaluation tools, for evaluating current and potential environmental impacts of products, and for manufacturing, management, disposal and recycling processes. There are various organisational systems for national and international ecological policies and eco decoding tools for translating quantitative values to qualitative results; for designers and outside developers of the eco engineering area.

These eco design methods can produce different levels of qualitative and quantitative value and are gaining credibility for logical results, which use more complicated and required more sophisticated processes. Hence, developers should find and select the appropriate tools by considering the value of marketability, product values, potential expected environmental risks and consumer demands. For example full-scale LCA, which was used in this research, has currently become the most general evaluation method and there is recognition that tools can cover wider environmental factors and impacts logically than other existing tools. Consequently, many global companies such as Nokia, Sony and Samsung have used this method for making the Corporates Social Responsibility (CSR) reports (see chapter 6).

Many different eco design, evaluation and decoding tools can provide logical background resources, reflecting consumers' and markets' diversified requirements to the designer which may achieve eco design fulfilment for economic, social and environmental benefits.

3.2.4 Categorisation of eco design tools

- Categorise eco design tools by impacting on the product life span and areas of effectiveness**

- Introduction to the adopted eco design tools in this research

As can be seen in figure 3.12, there are various eco design tools, which have different roles and impact on differing product lifespan areas such as production, usage, disposal and recycling. The features of design approaches can also distinguish those eco design tools to functional, aesthetical, technical and structural approaches.

Figure 3.12 shows the current existing eco design tools and effectiveness during the product lifespan. These were mostly developed in the engineering area and examples applied to industrial design for mass production, were very difficult historically. However large sized companies, particularly Nokia, Sony and Samsung have only used quantitative eco evaluation tools such as LCA to prove their products for eco product certification. Figure 3.12 presents 35 eco design (or ideation) tools; 7 from production, 16 from usage, 5 from disposal and 7 from recycling.

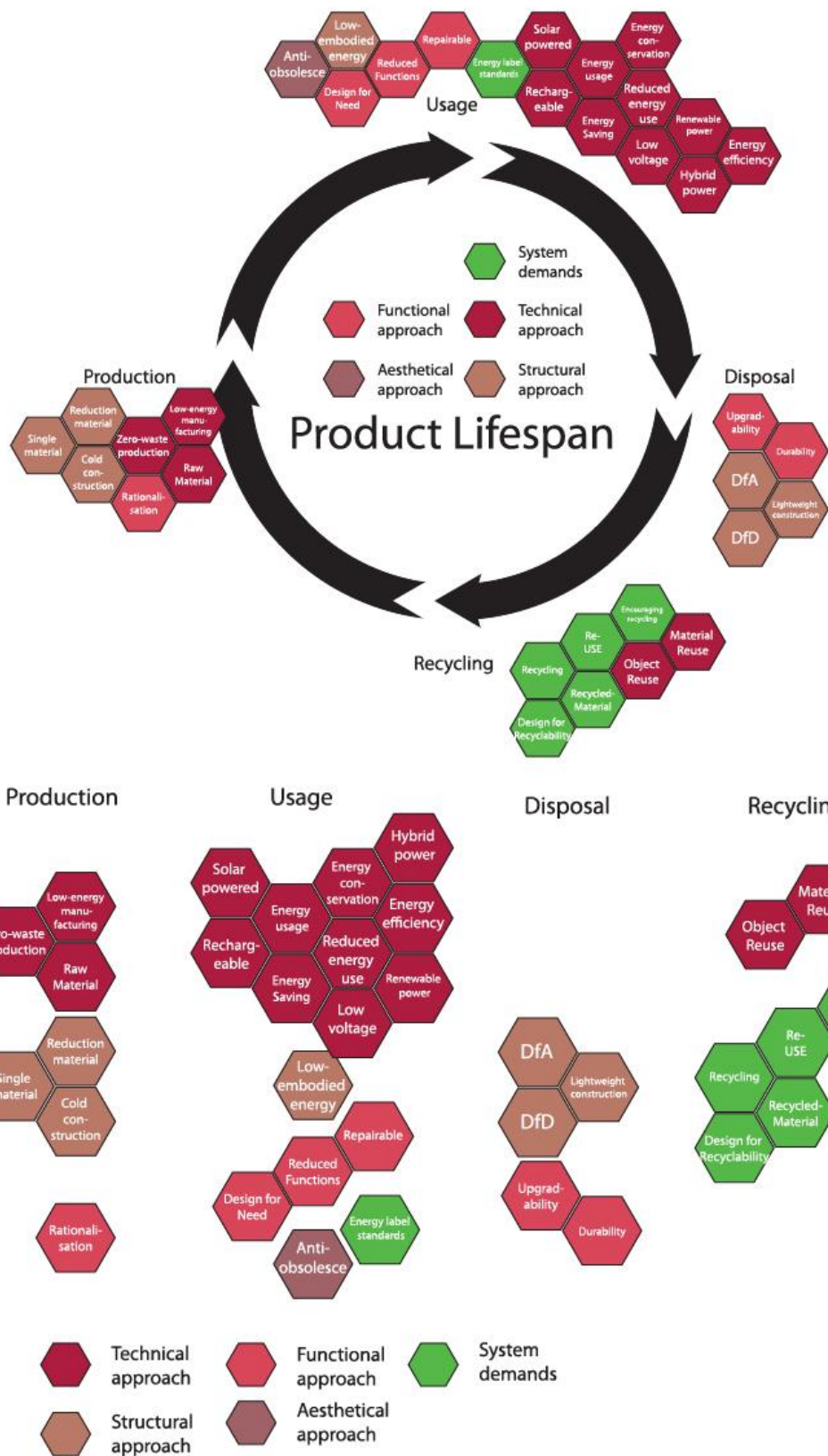


Figure 3.12 Categorised eco design tools by product lifespan and tool approaches.

Those tools have different features and characteristics and effectiveness to the environment. At the production level, most tools approached structurally and technically because major issues were focused on considering the environmentally friendly production processes, finding better effects for the material consumptions and reducing emission and manufacturing process times. This level of process included shipping and collecting raw resource, which was a starting point for the quantitative evaluation. Simplified production processes and the construction of low emissions processes may be the most effective solution at this level, however changing manufacturing process or re-considering management systems made it very difficult to solve design issues and also demanded high expert knowledge, cost and time.

Ten eco design tools use technological approaches in the current research for usage levels and due to high engineers usage, and high tech developers rather than designers' usage, marketers and other areas have focused on developing and inventing alternative energy, solar power and reducing energy consumption. However Anti-fashion and Anti-obsolesce, approached only aesthetic issues and were applied to extend customers' emotional fulfillment.

Some of methods can be exemplified such as high end brand jean has been used natural material and raw material and this can be driven by Raw material method. According to this example, eco design approaches can be impacted to marketing, advertisement, production processing and shifting design.

There are two major concerns; cost saving and increasing disposal efficiency through reduced disposal processes and raising recycling rates and reusable components, by considering alternative materials and the unification of assembly at disposal level. Most tools at disposal level influenced the recycling level, which predominantly cannot work alone. However, the use of recyclable materials and consideration of reusable structures in the design perspective demands many diverse systems such as recycled material collecting systems, social awareness and national recycling facilities.

Whilst there are numerous design methods which support eco-design, little cross-comparison has been undertaken, particularly comparative benefits in specific sectors. Approaches can be categorised broadly into 8 types: (i) Material reduction (including zero-waste production); (ii) Energy saving; (iii) Anti-fashion; (iv) Durability; (v) DFD (Design for Disposal/Disassembly); (vi) Rationalisation (reduced functionality and design for need); (vii) Upgradeability; (viii) Recycling.

Starting with product planning, there are Anti-obsolescence, Anti-fashion, and 'Design for Need' approaches, which all focus on the fulfilment of consumer purchase demands. Anti-obsolescence and Anti-fashion stimulate consumer's aesthetic demands, maintaining the consumer's concern for the product. In the case of the 'Design for Need' method, this is focused on the exclusion of unnecessary functions within the product as early as possible, to achieve maximum product lifespan extension, reduction in material and energy usage, and maximising usability. This method may build the relationship between both user and product, extending the product lifespan and linking this to the concept of 'sustainable design'. (Conversely, trends towards product and media convergence (see later) make a case for increased functionality, on the basis that reduced product duplication limits the total range of artefacts produced).

Other methods - such as "cold construction/manufacturing", "zero-waste production", "low-energy manufacturing and assembly" and "innovation within traditional low-impact technologies" - are related directly to manufacturing rather than design. To achieve this, designers have to engage with manufacturers at the planning stage, long before production; "single or non-material" methods are also included in this category. For energy saving and resource reduction during product usage, a range of methods are available, including 'Reduced energy use', 'Low-embodied energy', 'Energy conservation', 'Energy efficiency', 'Low voltage', 'Solar powered', 'Hybrid power', 'Rechargeable', 'Integrated energy control systems', 'Renewable power' and 'Energy label standards'. In enforcing the Kyoto protocol, energy savings and CO₂ reductions discharge can be traded for increased quotas for goods, thereby promoting this as a key environmental technology for future trade advantage.

The methods of Sustainable Design, Design for (ease of) Maintenance, Durability, and Upgradeability and Ease of repair/reparability are used for extending product lifespan. These approaches can be subdivided into three categories, which are: (i) the extension of product lifespan by reinforcing durability, (ii) the upgrading or tuning of a product, and lastly, (iii) the repair of a product. These methods have the same aim, extending product lifespan, but the significant weak points of two of the methods are their consideration of physical lifespan only. In contrast, upgradeability considers the affection for the product, maximises use-ability, and aesthetic and functional extension.

The environmentally friendly methods of DfD and lightweight construction offer effective product disposal, whereas product recycling (where the artefact is not broken down into its constituent parts) is covered by Recycling, Design for Recyclability (DfR), object reuse, material reuse, and encouraging recycling approaches. These methods can be categorised as product recycling and the use of recycled resources.

A case study approach had originally been planned, which sought to undertake a series of semi-structured interviews with senior management and designers within two Korean electronics large sized companies. These were to be supported by a series of ethnographic studies, shadowing the use of eco-design tools within the design department at each organisation.

These interviews and research implementations had illustrated the gap between advertisement and current their implementations and also demonstrated company's ranges of investments for environmental friendly product development. This approach deducted different understanding rates of 8 eco design methods in different level of interview targets and found the possibilities for adopting these methods to product development.

Through this interview, the research could provide background data for establishing the research directions and realistic actions, policy and ideas in the industry field regarding sustainability.

3.2.4 Summary

This chapter demonstrated each definition, type and feature of eco design methods and standards of categorize; furthermore, particularly for this research, this also shows evaluation means way to select the methods and current barriers and potential opportunities of eco design methods.

The literature review showed current various eco design method however it is difficult to find previous examples, where eco design methods and applied to product design and development in the business field. Moreover there is a serious deficiency in data in the design area compared with other areas such as engineering and marketing during researching literature review.

Eco design methods can be categorized by the product lifespan (production, usage, disposal and recycle) integrated with the different approaches of each eco design method as section 3.2.4. Through this grouping, designers can find and adopt the appropriate eco design method, which can correspond and support with developing target products, for example Design for Disassembly (DfD) and Reduced material methods are more effecting for products, which require heavier manufacturing processes and components. However, these effective methods pose serious barriers to designers that require quantitative evaluation data.

In the Green Round era, which environmental consideration has to connect to economic benefit quantitative eco evaluation methods can generate comparable data in various environmental impacts and these illustrate rates of environmental impact within the different environmental impact categories.

The Eco Compass visually represents quantitative data (such as LCA data) to compare different sectors. Particularly provide effective resources to industrial designers and marketers by showing the strong and weak points in different environmental factors.

This chapter showed definitions and categorizing of each eco design method and also demonstrated and selected appropriate methods for the research. Based on the background, the research will implement pilot studies & evaluations in chapter 6,7 &8.

Summary of chapter 3

- Each eco design method have different contexts and can be grouped in product lifespan (production, usage, disposal and recycling) and different approaches
- Eco strategy wheel method highlights the strengths and weakness by reflecting the appropriate eco design methods for the designers and ranked 8 eco design methods from figure 3.12
- Historically eco design has gaps between industries and business however since 2000, as RoHS, WEEE and Kyoto protocol came out, the eco design area has been changed to more practical and detailed
- To adopt eco design methods, it needs to have designer's perspective, which is suitable process and making similar results and also reflected outside factors such as market shifting and technical achievement

Chapter 4. Framework of the eight eco design methods

Precis of chapter 4

- Determine the hierarchical linked elements frameworks for each eco design method
- Determine the influencing factors and effectiveness of eco design methods by different user types (light & heavy user)
- Explore key issues, effectiveness and strengths in different product lifetime by each eco design method
- Exploring the potential issues in different phrases of product lifespan
- Finding relationships between eco design methods and international environmental regulations & business requirements

This chapter will show the maximised estimations for each eco design method through estimated optimistic positioning (this research framework is established by based on combined product lifespan and Eco compass's approach), for each stage of product lifespan and the major influences within the different user groups. This estimation will be used as a guideline for chapter 9, which finds research results through the comparison of conclusions and hypothetical results. Moreover, this chapter will study the positioning of each eco design method for different conditions and impacts. The research illustrations will be used in the background for analysing business perspectives for each eco design methods' value.

4.1 Framework for the comparison of eco design methods

The product lifespan has four core stages; production, usage, disposal and recycling, this theory follows 'cradle to cradle' however, the traditional concept of 'cradle to gate' has not been included in the recycling stage (Business week 9. 2007).

Figure 4.1 demonstrates the different purposes of different stages in the product development cycle and shows the environmental burdens within the product lifespan

and moreover potential environmental impacts, which can occur by shifting the leaders and followers or market and manufacturers' conditions, such as changing design trends or developing new technologies, which can drastically increase environmental impacts.

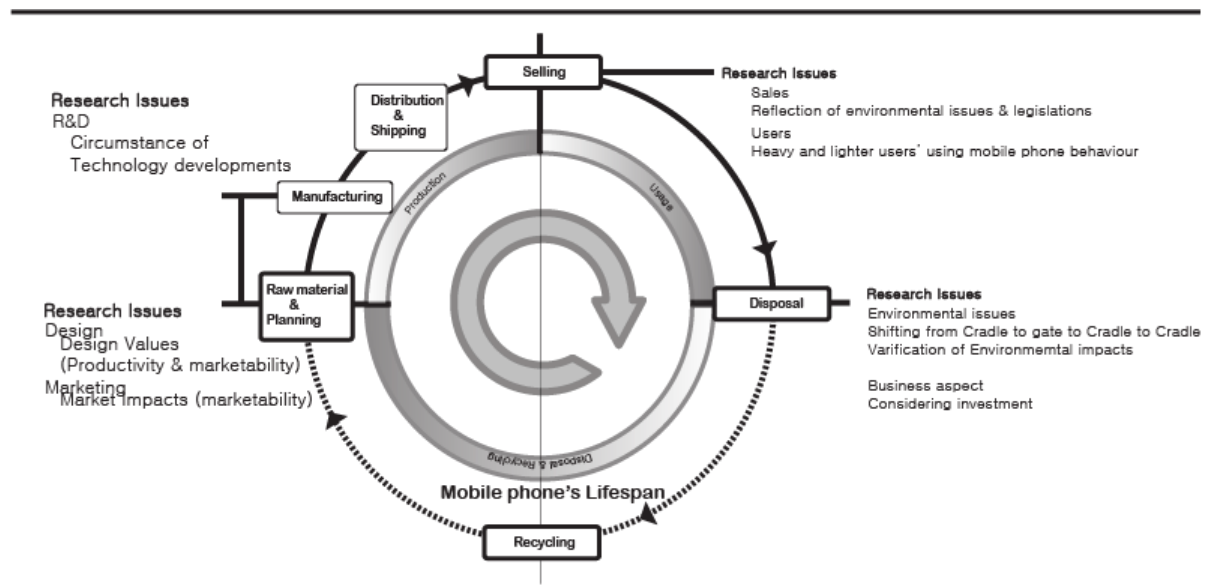


Figure 4.1 Position for each research issue at different stages of the product lifespan

The research issues, which are positioned in figure 4.1, will reflect the findings of the research results by comparing environmental and business perspectives for environmentally friendly design methods. Figure 4.1 illustrates the crucial influences in deciding environmentally friendly product development through reduced environmental impact or increasing recycling rates at different stages within the product lifespan. According to figure 4.1, in order to implement effective design work, this requires consideration of the values from early stage product development processes, therefore eco design should consider reflecting from the product planning level stage to produce the market and manufacturing values which can show that current eco design or eco-friendly products have followed the traditional industrial design principles, which are based on marketability and productivity.

Green marketing design, which appeared recently, is the convergence of commercial enterprise issues and traditional business issues. Current environmentally friendly achievement can attain economic benefit but also produces a wide range of

intangible benefits such as company reputation, management and advertisement (Jay, Leslie, 1990).

In conclusion, the positioning of each research purpose and target will provide the fundamental estimate to analyse and evaluate the current & potential environmental impacts in producing the ranking for environmental enhancement. This positioning can also be background information to help to estimate and forecast issues in producing research results for the effectiveness in a business perspective; from different business areas such as marketing, design and R&D.

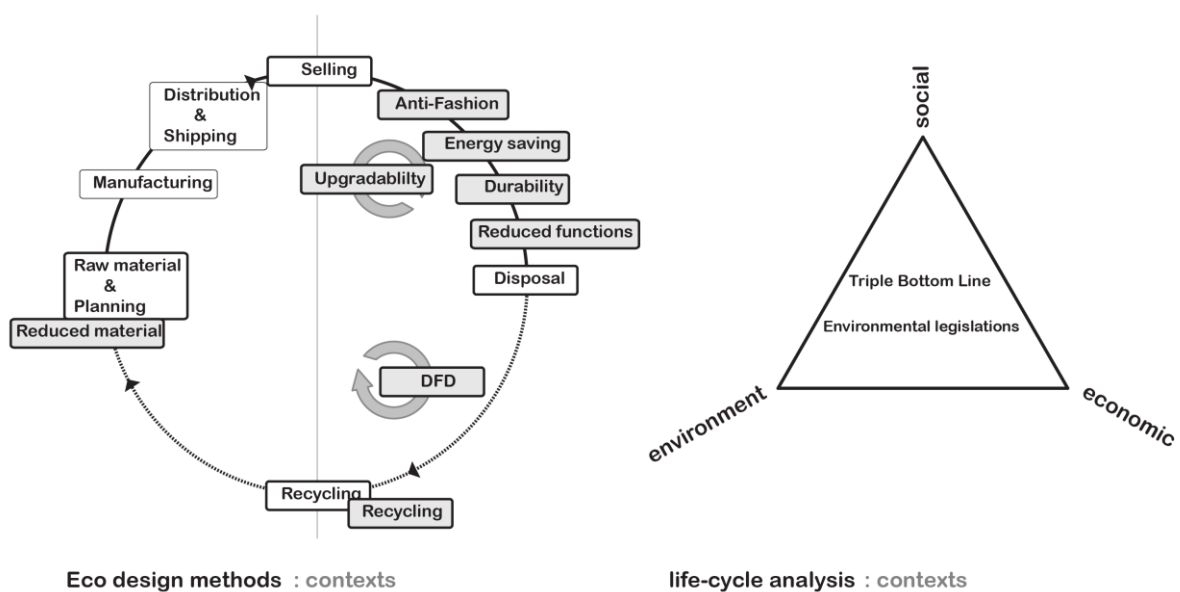


Figure 4.2 Contexts of eco design methods and life-cycle analysis

Figure 4.2 illustrates eco design methods applied in this research, which can be deployed on the product lifespan. The eco design methods have worked on the product by extending product lifespan or reducing environmental impact at different stages of product lifespan. Consequently, each eco design method has a distinguished strength; for instance, the reduced material method works more effectively at a production level and focuses on reducing the environmental impact through saving resources, whereas the reduced function works on usage levels and implements improvements to reduce energy consumption by establishing the priority of functions.

According to a report titled 'Development of eco design road maps (2012)' by the Korean Institute of Industrial Technology Evaluation and Planning, they found significant issues that shifted environmentally friendly product paradigms from eco products based on the emotional appeal or non-functional approaches. This means that these types of product only focused on knowledge and understanding, however the environmentally friendly products reflect more on commercial benefit and market trend since major international environmental legislation appeared and environmental agendas have become important public issues.

The development of triple bottom line (TBL) was to increase marketability, where even environmentally friendly products should follow fundamental market principles through balancing three key issues: environmental, social and economic benefits (Elkington, 1994).

To more effectively implement eco design methods in product development, this research reviewed the characteristic features of each eco design methods on the product lifespan. For example, during usage of the product the relationships related to service can be significant, such as between users and service providers or products and functions. Therefore in order to reinforce the product lifespan, the usage level energy saving method is more focused on the battery efficiency or power consumption rather than saving power consumption in the production process.

Another example is the upgradability method, which is located on right upper side of figure 4.2, because this method only has influence during the usage level. The DfD method also affects the disposal and recycle levels rather than the production level. This method may reduce disposal time and cost and it may be able to increase the percentage recycling. According to this hypothesis, each method has a different role within the eco-design process.

This research was established through the concept of TBL, which states that eco design methods should not only undertake environmental preservation but also eco products need to produce economic benefit at different stages and with different characteristics in the product lifespan.

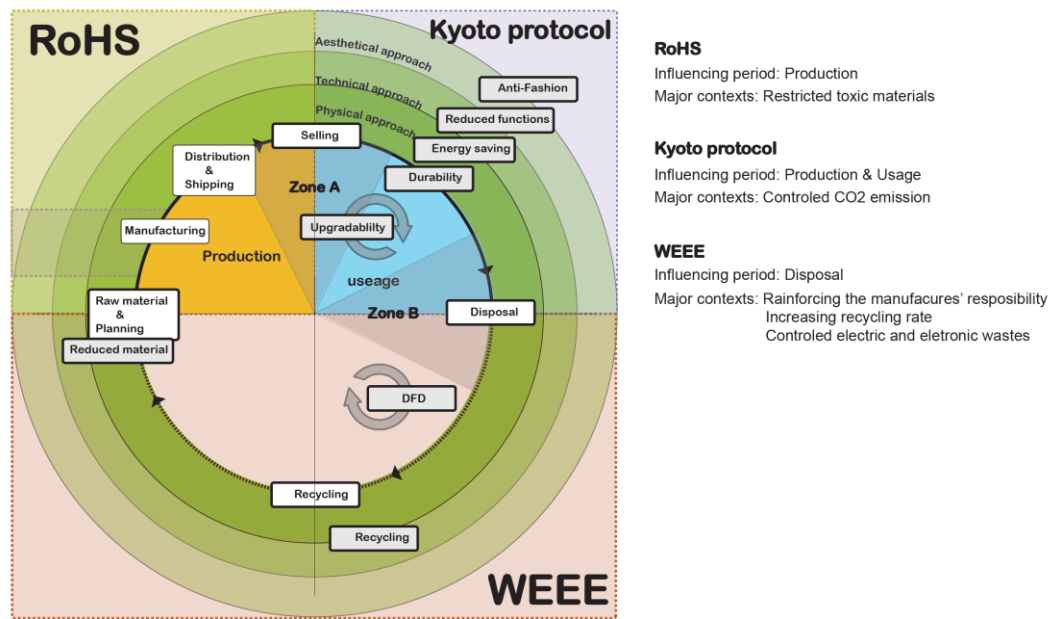


Figure 4.3 Influences between different approaches of eco design method, product lifespan and international environmental legislation

Figure 4.3 illustrates the relationship between different approaches of eco design methods; physical, technological and aesthetical approaches and major international environmental regulations, which have most influenced the mobile phone industries since 2000. According to this analysis, five out of eight eco design methods; upgradability, durability, energy saving, reduced function and anti-fashion, which were applied in this research were positioned in the Kyoto protocol area.

However, in applying these eco design methods to product development, disposal will move to zone B, which means extended product lifespan or it can influence the increase in efficiency of manufacturing or raising investment effects through the use of the reduced material method, which then impacts the product lifespan. For each eco design method, the DfD, Upgradability and recycling methods not only require physical and technological environmental approaches but also need recycling systems and facilities to increase the collection rates and speed up material verification, new structures of markets to deal with international environmental legislation and government support.

The basic principle of the reduced material and durability method is to reinforce the housing and physical packaging to extend the product lifespan. According to section 2.6 in chapter 2, the major markets for the Korean mobile phone manufacturers are China and the US, and these markets have followed WEEE and the Kyoto protocol. Hence, this analysis shows the priority of significant rates for Korean mobile phone industries through relationships between major market and international environmental legislation and according to figure 4.3, DfD, recycling, energy saving and durability can potentially be the most effective approaches.

4.2 Estimation of maximised results of each eco design method within the product lifespan

This section will illustrate and estimate the maximum effectiveness of each eco design method within the product lifespan through differentiation by heavy and light users. Definitions of different user groups are in Appendix 5 and this analysis was implemented by general interview and expert interviews, see chapter 7. To summarise the features of these groups, the heavy mobile phone users have used the product on average for 7 hours per day in contrast to the case of light users who used the phone for 2 hours per day opposed to general users who used the phone for 3 hours per day. According to interviews this usage gap produced battery lifespan gaps and moreover emotional and functional satisfaction rates of the product, which influence product lifespan.

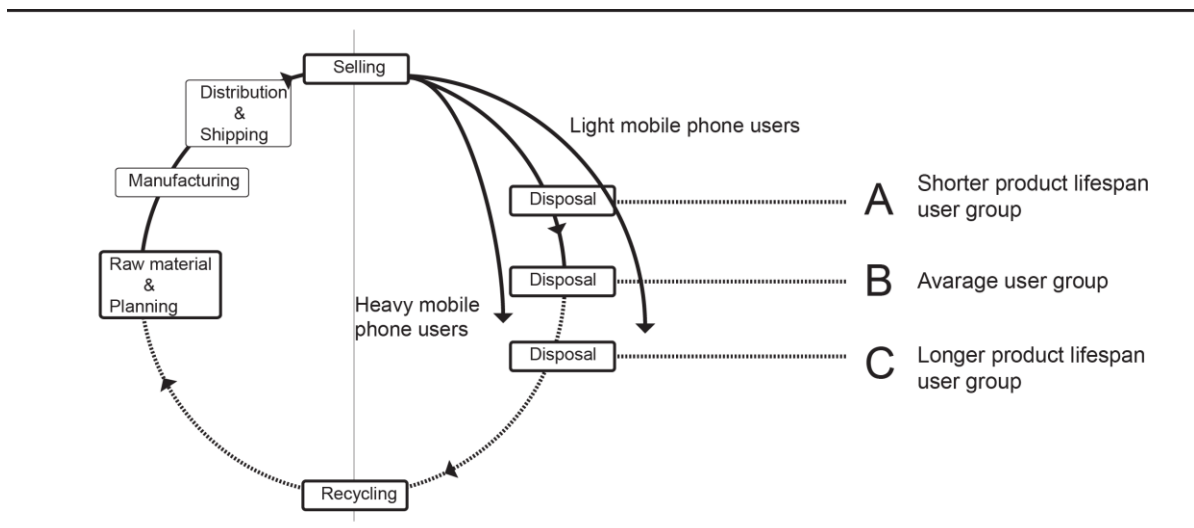


Figure 4.4 Different product lifespans by user groups

To define the user group required consideration of different outside factors, which gave various influence to extend product lifespan for example, the heavy user's mobile phone may have a shorter product lifespan through spending more energy and using heavier process levels more frequently, requiring more functionality and also this group want larger sized LCD screens and professional functions.

Selecting mobile phones for light users may be focused on price and service rather than functionality or technical options. According to user group interviews, generally heavy mobile phone users who use the phone for a longer time and more frequently use mobile phones more functionally, that save personal and business information, and therefore this group is more dependent on the mobile phone compared to the other groups. The physical product lifespan of heavy users' is shorter than for lighter users through consumption and faster obsolete batteries and lifespan of the display. The interviews show that mobile phone users are sensitive and competitive emotionally, meaning heavy users (particularly younger age groups) have been influenced by other people's perception of their phone and design trends, therefore this types of user group recorded the shortest change frequency compared to light users in old age groups.

Through this framework the researcher can estimate the effectiveness of eight eco design methods; durability, DfD, recycling, anti-fashion, reduced function, reduced

material, energy saving and upgradability and can establish a strategy for discovering research results.

4.2.1 Estimation of maximising the results of the Upgradability method

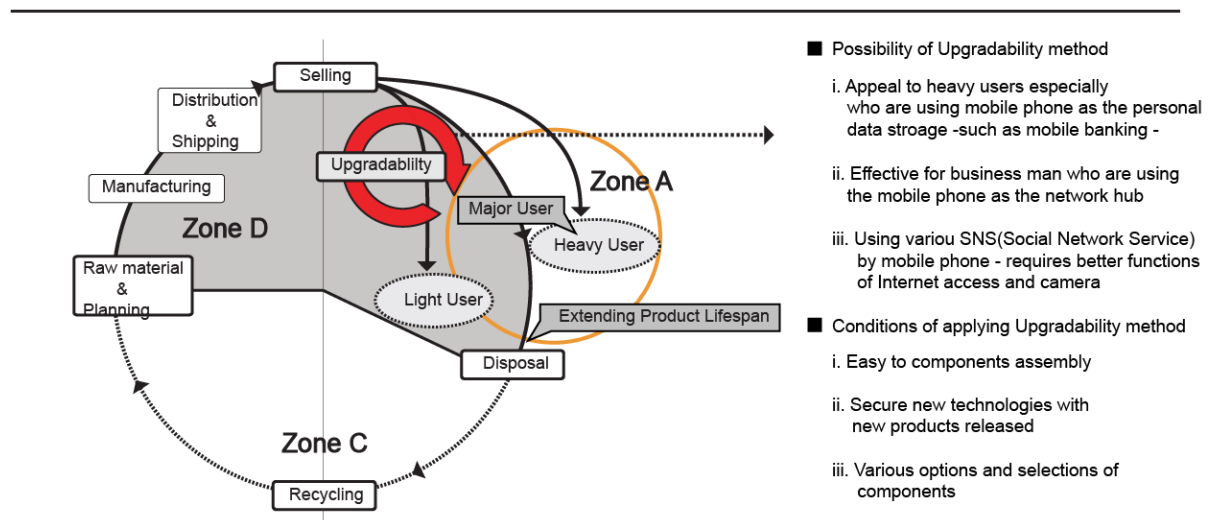


Figure 4.5 Estimation of the effectiveness of the upgradability method

Figure 4.5 shows the estimated effectiveness of the upgradability method. According to figure 4.5, zone C could be reduced by applying this design method and in contrast could lengthen the product lifespan from the starting point of disposal. This method may work on zone B and zone A by replacing components or physical product upgrades, however this method can be more efficient for heavy mobile phone users because this group of users has more concern regarding new functionality or customising the mobile phone as opposed to light users. It also has a negative regard for the environment.

Generally when upgrading products they need more / updated components which produces more e-waste. Therefore this method will have more effect than current mobile phones being buried because currently almost all mobile phone components have been buried which decreases recycling percentage rates (NCPD report 2008)

Figure 4.5 shows the effectiveness of the upgradability method and this can extend the product lifespan, furthermore this also provides the basis for customising products' structures and functionality for different users' behaviours and demands.

Products made by this method can give more emotional and functional satisfaction. In addition, upgradable products consist of modular structure or easier structures for assembly and disassembly, therefore this method can connect to the repairable approach as well.

The upgradability method requires more investment and effort to produce and also requires consideration of sophisticated production processes and product structures. Consequently for instance, to realise this method demands more consideration for product attachments and detachments of PCBs, internally and externally. However the biggest barriers for realising this method could be i) this method requires component market rather than product markets therefore to apply this approach needs to modify structures and systems of markets to better focus on the components. ii) To apply this method requires manufacturers and service provider' knowledge and understanding. Since mobile phone development, the market has rapidly grown (chapter 3) and in 2013 mobile phone users are the largest single market of a single product category (chapter 3). Therefore short-term manufacturers and service providers do not need to change the market structure with great risk and investment, iii) The R&D and designer requirements. It is a different method than for usual mobile phones, which they have already been developed. Moreover this needs special design and planning for the upgrade and tune up kits. As this thesis explained previously, most producers including Korean manufacturers are more focused on production costs or benefit rather than impact on the environment. This is an example of the applied upgradability approach.



Picture 4.1 Example for upgradability method (Equinox)

(<http://www.yankodesign.com/2013/03/04/customizing-the-camera-options/>, Access date: 4th October 2013)

This camera is manufactured through upgradable consideration and called 'Equinox by Yancodesign US'. The concept for this camera is to upgrade the specification and functionality for user's needs and behaviours. In particular, the camera used a different lens with customised functionality to the same body and CCD (Charge Coupled Device) therefore, the target customer for this camera can be from general user to professional photographers.

Few conceptual products have been achieved using the upgradability method, however it may be difficult to find upgradable design because to develop this type of design requires more consideration for repairable structures and upgradable components. Moreover to achieve the upgradable design, it needs to set up new types of markets from the saleable products to product components and also requires a wide range development strategy from marketers, R&D and designers.

4.2.2 Estimation for maximizing the results for the Durability method

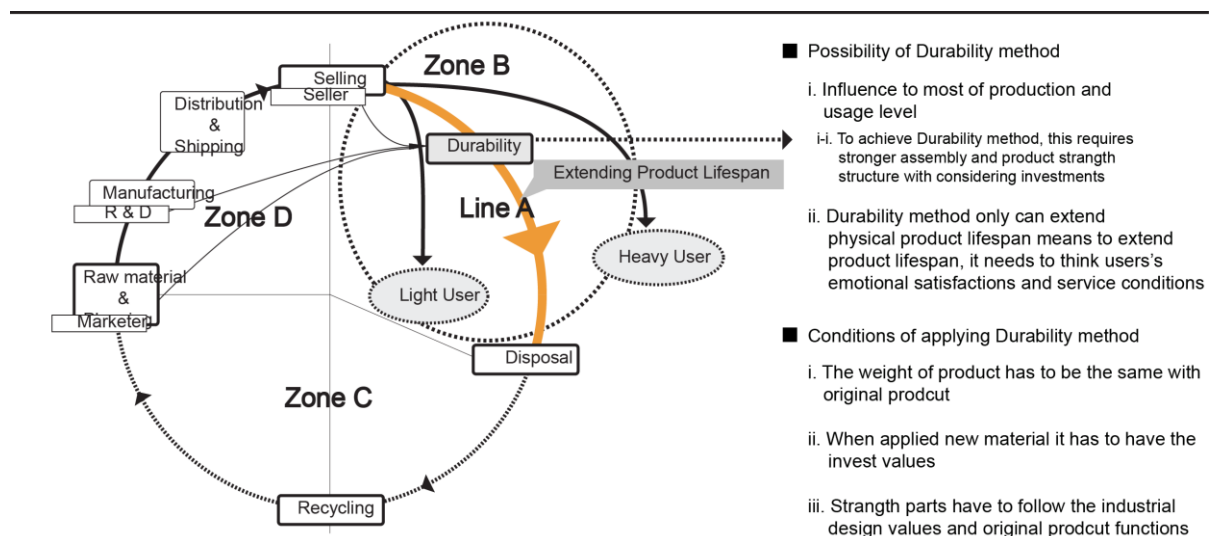


Figure 4.6 Estimation of the effectiveness of the durability method

In figure 4.6, applying the durability method can extend the usage time. The durability method reinforces product strength particularly through the use of new materials or considering stronger structures. This method influences the product lifespan directly, however the weaknesses of this method are i) this method only considers physical factors therefore to effectively achieve success with this method

requires consideration of users' emotional satisfaction, ii) traditionally stronger products have been much heavier than normal products and the weight differential can off put decision makers with customer purchasing, particularly with some hand held product categories such as mobile phones. iii) The durability method focuses on housing design or assembly structures normally, therefore some previous sustainable design products which were developed through the durability approach were very blocky and had bold designs. Despite using this method, it needs to follow industrial design principles, with value for the emotional, functional and aesthetic balance to appeal to customers.

The extended usage time may influence heavy & light users, however in the case of the heavy user groups may not attain the impact as much as for light users, because physical obsolescence may be a major cause for changing the product. In this group, particularly the older age user groups, they have not thought about the product service contract or the new design. Hence, according to this analysis and general interviews in chapter 7, light users have been influenced by the product price against service quality, therefore durability and strength of product can be a significant factor when deciding product selection.



Picture 4.2 Cologne 2011: London designer Harry Thaler's Pressed Chair

(<http://www.dezeen.com/2011/01/18/pressed-chair-by-harry-thaler/>. Access date: 5th October 2013).

This example demonstrates that despite reduced material the product has higher strength in the frames through structural design. This chair is manufactured by

pressing 2.5mm-thick aluminum sheet and the pattern on the surfaces makes the structure stronger.

In conclusion, when applying the durability method, if the product demands more material use or better designed structures then this may not be defined as an eco-friendly product. To accomplish the durability method, the design needs to i) find a stronger structure within the same material condition, ii) consider design or ways to manufacture for higher strength and iii) find alternative materials to deal with consumer's demand and the purpose of the eco-design method.

4.2.3 Estimation for maximising the results of the Design for Disassembly (DfD) method

The DfD method can be the most effective method to increase recycling rates for the product. This research showed the difficulties of mobile phone recycling because in particular the recycling stage requires simplified structures to products, such as disassembly and verification, collection and reuse of the components. For instance, a mobile phone normally has 7 to 9 bolts (1 or 2 bolts are hidden and some of them have special attachments for disassembly) and moreover entire mobile phones have different structures for assembly.

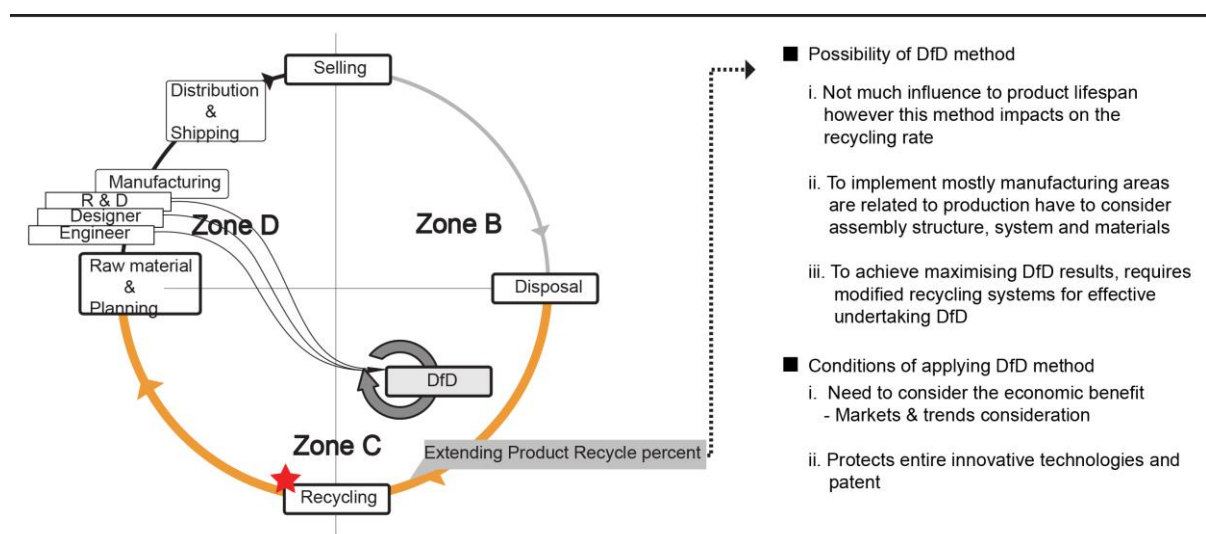
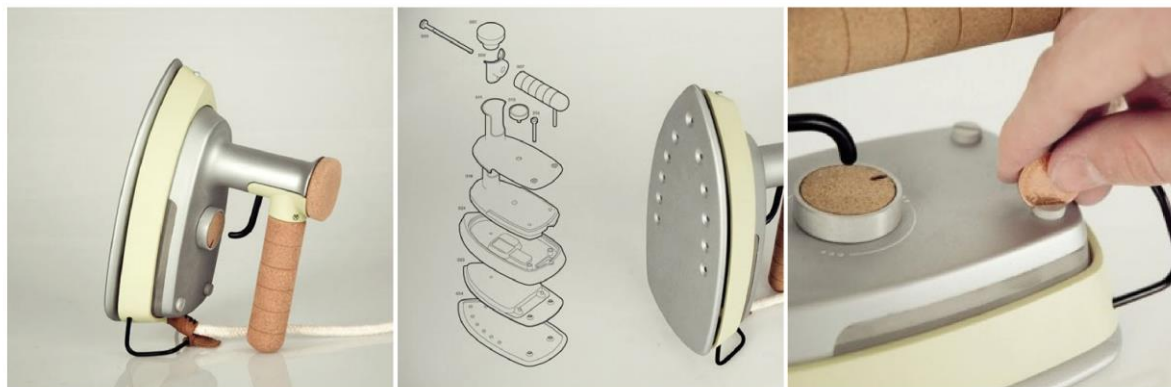


Figure 4.7 Estimation of the effectiveness of the DfD method

The purpose of this design method is to increase recycling percentage rates with the efficiency of manufacturing and the disposal and this method may also help with easier repairs and upgrades. However, for this method to appeal to potential customers it needs to find a marketing perspective for advantage because DfD is not a strong tool for emotional and functional appeal to customers. In conclusion to apply this method i) R&D and designers have to consider effective ways to appeal to customers and also although DfD may have a very strong advantage in an environmentally friendly perspective, this needs to have the marketability. ii) Designers, engineers and marketers have to work as a team for product development. Undertaking the DfD method requires more sophisticated implementations such as knowing markets and technology conditions / status.



Picture 4.3 The DfD design method for an iron

(http://www.rnrassociates.com/wordpress/home-products-redesigned-to-be-easily-fixed-cod_cool_product_design.html Access date: 17th of October 2013)

Referring to this example, this product applied the minimised assembly structure through DfD concepts for easier repair and maintenance. In addition, this iron is designed using an intuitional approach, using moderate decoration and applying less functionality for more recognisable and higher usability. This design also used exposed assembly structures, which can be assembled or disassembled through finding tools such as coins to achieve a higher rate of maintenance for the product.

4.2.4 Estimation for maximising the results of the Reduced functions method

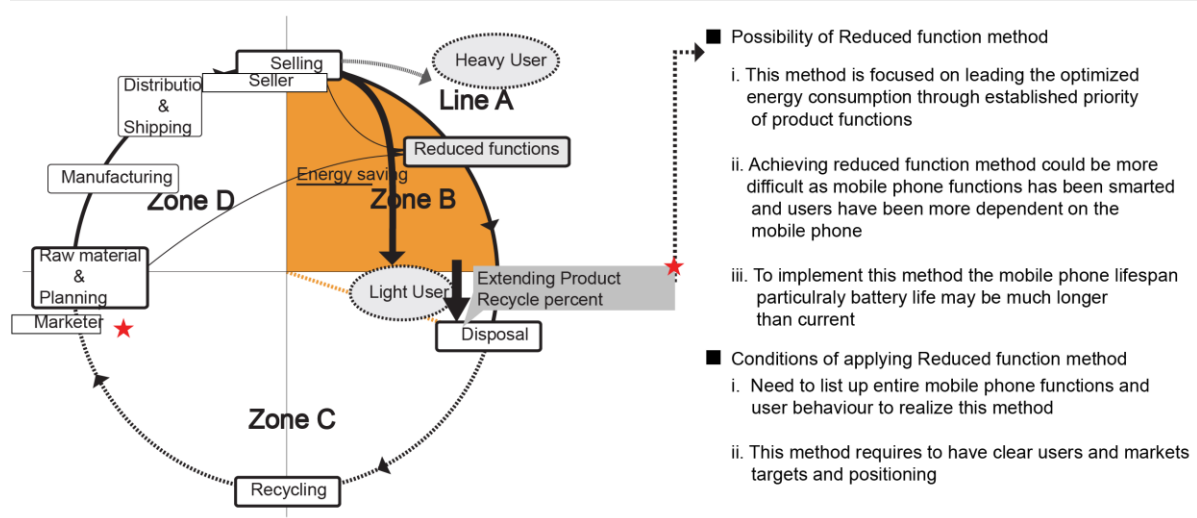


Figure 4.8 Estimation of the effectiveness of the reduced functions method

Figure 4.8 shows the effectiveness of reduced functions. The purpose of this method, given products have been getting more complex and intelligent, is that users have used the product functionality in a limited way and different product cultures and user behaviours have been used for product functionality. Consequently this method simplifies the object and reduced energy waste and material consumption by prioritising functionality and user behaviours. For instance, applying the reduced function method to a mobile phone design, in particular 2G (2nd Generation) phones have converged with optional functions such as digital cameras and MP3 players. The design will be more focused on traditional objects and archetype images. Nevertheless, this research has a limited focus on only usage levels to effectively reduce functionality because each evaluated result can balance the entire eco-design method and also calculate manufacturer' profits through applying this method in the production and disposal levels, which could not be found at a research level.

According to figure 4.8, Zone B illustrates that applying the reduced functions method has produced the effectiveness of extending product lifespan because this method has impacted the light users, especially old age groups and concentrated on using traditional mobile phone functions. The reduced function method may also be an effective design and marketing approach for these types of user group, as newer

smarter mobile phones have been more difficult to learn which requires clear user and market targets for applying this method. Hence, in this analysis, the eco-design method is connected to marketers and sales people because these areas could have negative opinions. As a consequence, generally marketers and sales people in the electronic product company target a wide range of customers, however this method is limited to a target audience or having a narrow range of potential customers. In conclusion to apply this method, requires that i) one establishes the list of functional priorities, ii) one finds specific markets and user targets and iii) one builds the social, economic and environmental validities.



Picture 4.4 Example for reduced functions method (IP65 Keyboard)

(http://www.key-tek.cn/en/products_show.asp?aid=287&id=1039&flag=0&act
Access date: 18th October 2013)

This example presents the application of the reduced function to product development. Referring to the product, applied track ball and simplified keypads reduces the amount of keys to design this keyboard, designers needed to consider user behaviours and functional importance. According to the reference, originally the design concept for this product was to reduce error rates.

In conclusion, this method has not been found in product development history through previous explanations, however as there are rapidly segmented user groups and more complex product functionality developing, this method will be an essential consideration within product development.

4.2.5 Estimation for maximising the result of the Recycling method

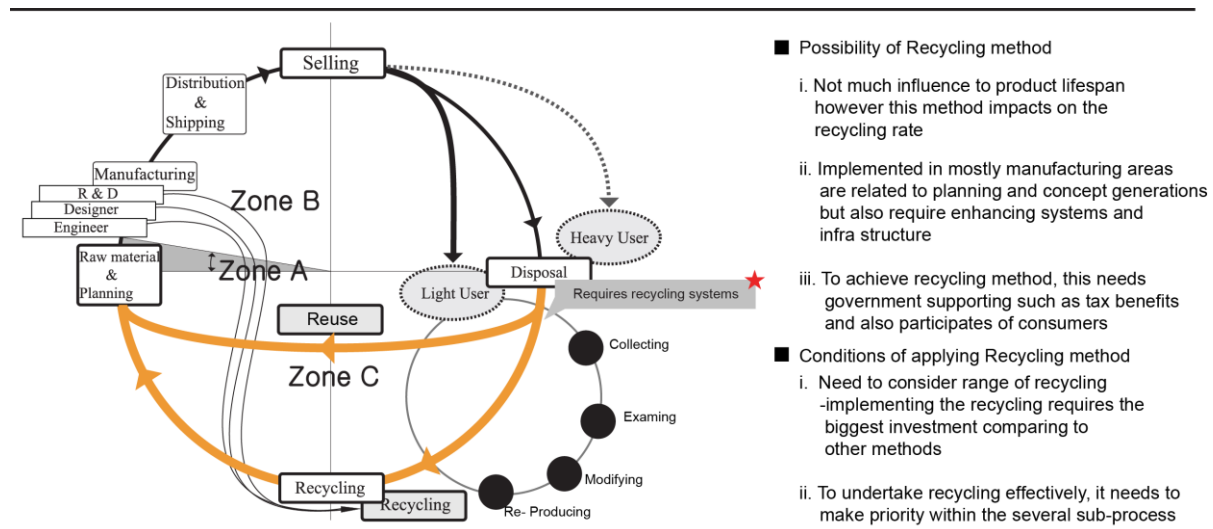


Figure 4.9 Estimation effectiveness of recycling method

This analysis shows the estimated effectiveness to applying the recycling method to product development. Currently 'recycling' has used a definition from using waste to producing products, to only collecting the waste, however a general definition of recycling is 'reusing or reproducing unused or disposed items to make valuable resources'. Previous definitions stated that recycling can mean i) reusing and reproducing waste and ii) collecting valuable items from waste (Young Ho Kim, 1991).

According to figure 4.9, implementing the recycling method requires a recycling process and systems for disposal of the product. To implement recycling processes requires waste collection, examination of the collected waste, treatment management and a reproducing process, however all responsibilities to establish these systems and facilities have been entrusted to manufacturers or providers, which demands huge investment. Therefore national governments support recycling in many countries, where most recycling is supported through governments.

In this analysis, the recycling method is applied in the product planning and design levels and at that time designers and engineers considered how to achieve or increase the rates of recycling. As a consequence, to accomplish recycling, it needs

consideration for i) what alternative or recyclable materials will be used in product development, ii) what and how products will assemble or disassemble, iii) what systems or facilities does the company currently have, iv) what current status of recycling technologies can be realised and v) what social, economic and environmental benefits can be generated.

According to this analysis, there is the reuse line between production and disposal and reuse may require less initial investment cost through reduced process and also can be connected from disposal to production without reproducing and reprocess. This analysis also shows that the recycling method, which only focuses on reducing waste rather than other eco design methods and approaches, such as increasing energy efficiency and extending product lifespan, hence this approach may not appeal to customers.

Recycling or decreasing waste has been a issue internationally by appearing in the international environmental legislation such as WEEE and has been the subject of environmental responsibility, which has shifted to manufacturers or providers. Consequently to deal with these diverse requirements, recycling has become socially acceptable and become an essential issue in product development.



Picture 4.5 Example for the recycling design method by Belkiz Feedaway (<http://inhabitat.com/portable-flatpak-high-chair-made-from-100-recycled-cardboard/> Access date: 18th October 2013)

The baby chair by Belkiz Feedaway is designed by recycling approaches and this can be used in any place and at any time by origami. The materials used are 100% recycled cardboard having minimum environmental impact and moreover this design can be adjusted in shape and height for dealing with different users' circumstances. This example implies that the qualities of the product satisfy people's concerns and this method needs to converge or follow traditional industrial design values for marketability and productivity.

4.2.6 Estimation for maximising the results of the Anti-fashion method

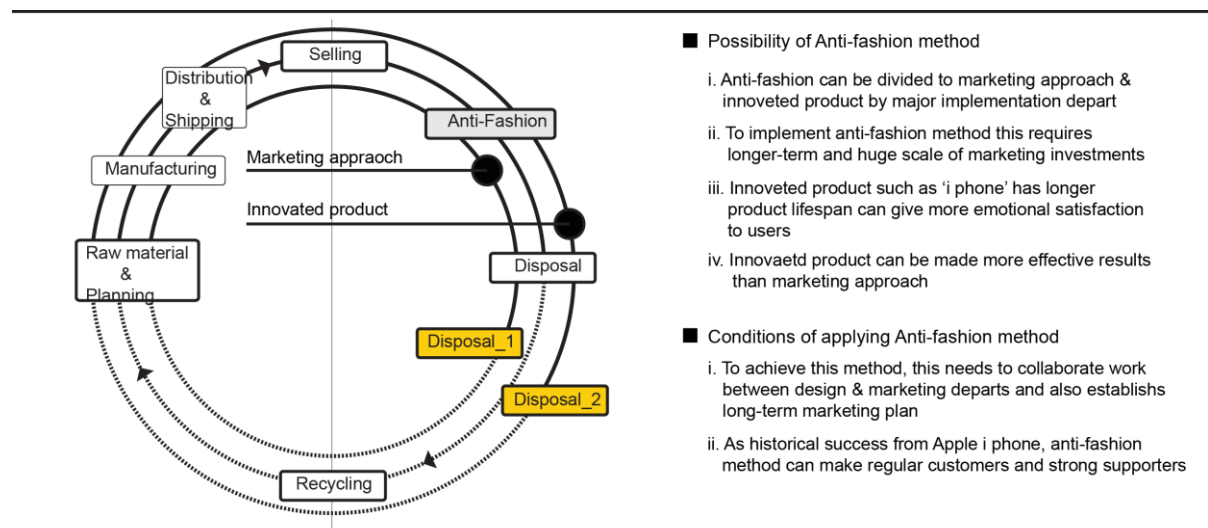


Figure 4.10 Estimation of the effectiveness of the anti-fashion method

Figure 4.10 describes the effectiveness of the anti-fashion method. To achieve this eco design method requires large-scale marketing support and the production of innovative products. For example, iconic products such as the i-phone (Apple) and the Dyson vacuum cleaner can be accomplished through anti-fashion naturally because these types of product may be informed by regular customer groups and media groups by giving distinguished emotional satisfaction.

However these cases are historical successes but required long-term research and large-scale investment. Generally the anti-fashion method has been undertaken by longer-term marketing approaches to enhance the users' emotional fulfillments.

Specifically, the anti-fashion method could produce the largest successful economic benefit whereas this also produces the largest risks through huge investment, therefore currently there are only limited manufacturers who can implement the anti-fashion method in global product development. This could also have a negative return on investment.

In conclusion, when applying the anti-fashion method, this requires i) finding the market possibility and technological differentiations, ii) setting up the systematic marketing strategies, iii) finding a balance between environmental and economic benefit and iv) evaluating economic validity.



Picture 4.6 Example for Anti-fashion method by Dieter Rams

(<http://www.fastcodesign.com/1672632/braun-reissues-a-dieter-rams-design-classic-the-et-66-calculator>, Access date: 20th October 2013)

This iconic calculator (Braun, 1987) designed by Dieter Rams can show the effectiveness of emotional success for anti-fashion. This product is one of the historical designs that represent modern minimalism industrial design and this product is proof that innovative design can lead to emotional inspiration for users. Referring to this example, to achieve anti-fashion requires significant conditions which are i) designers and developers need to understand the consumers common emotional and functional directing points, ii) to avoid developing a downgrade product, designers have to establish the importance ranking and balance between functional and emotional aspects and iii) anti-fashion requires large scale marketing

support therefore it needs to set up a strategic long-term marketing plan and identify marketing approaches.

4.2.7 Estimation for maximising results of the Reduced material method

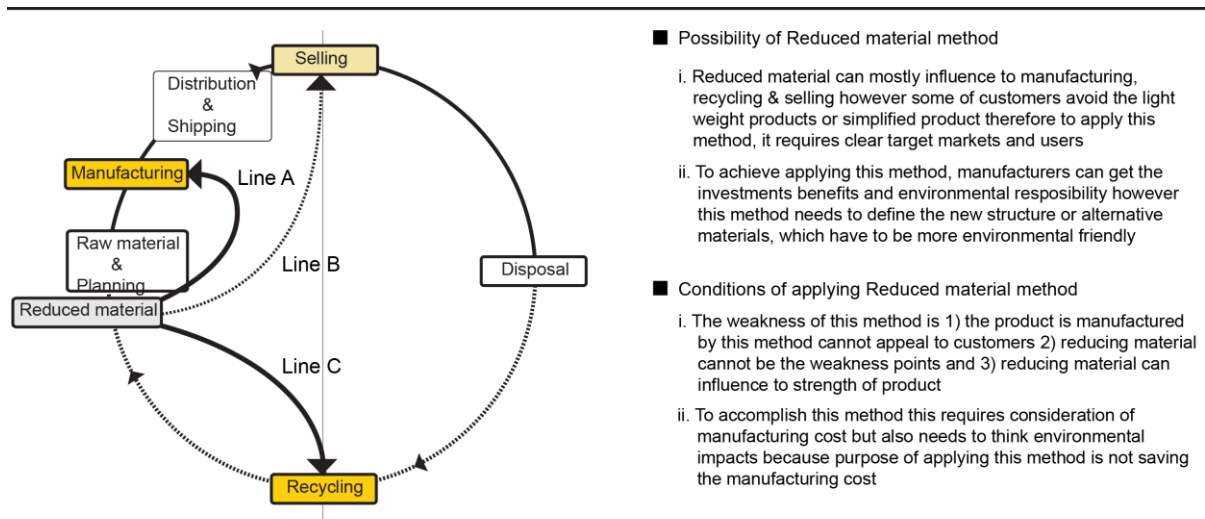


Figure 4.11 Estimation of the effectiveness of the reduced material method

In figure 4.11, reduced material may influence production and recycling during the product lifespan. The purpose of reduced material is for the preservation of rare natural resources and reducing waste through innovative assembly structures, whilst using alternative materials. Referring to this analysis, similar with recycling and the DfD methods, the reduced material method has no factors to appeal to customers, therefore this method cannot be used in a strategy for capturing markets or producing economic benefit.

If this method was used for the marketing approach or the environmental contribution through reasonable investment then this method can accomplish social and environmental achievement and can be connected to economic benefit in a limited way for manufacturers because e.g. the manufacturers found alternative materials were more environmentally friendly and less investment may be required for production.



Picture 4.7 Example for Reduced materials by Suck UK, Wooden Bulb

(<http://designgush.com/category/directory/suck-uk/>, Access date: 20th Oct 2013)

The Wooden Bulb design uses recyclable, very thin wood board for the package design. The achievement of this design is the application of new materials for packaging through aesthetic design consideration, this bulb design achieves a multi-task approach; packaging can also be used as decoration. There is a fence structure to protect the bulb and joints for aiding the assembly process.

Suck UK who designed this product shows the example to how to reduce the material through conceptual approaches and also provided aesthetic achievement through a structural design concept.

Through this example, the author considered the conditions to undertake the reduced material method, which requires i) detailed research about user environment and major user groups, ii) the purpose of reduced material having to follow the principles of environmental preservation rather than producing providers' economic benefits and iii) finding alternative materials to effectively cover the amount of reduction.

4.2.8 Estimation for maximising the results for the Energy saving method

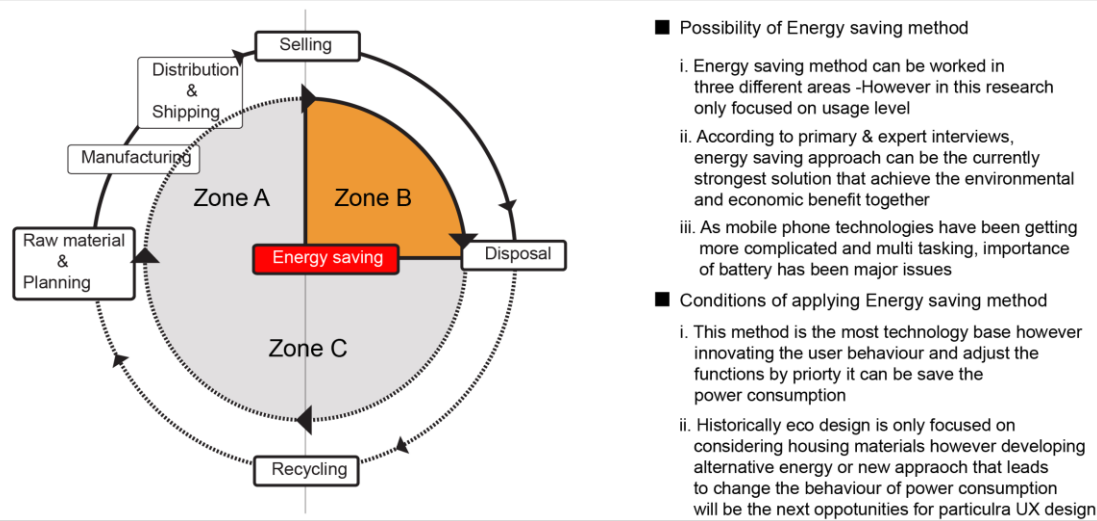


Figure 4.12 Estimation of the effectiveness of the energy saving method

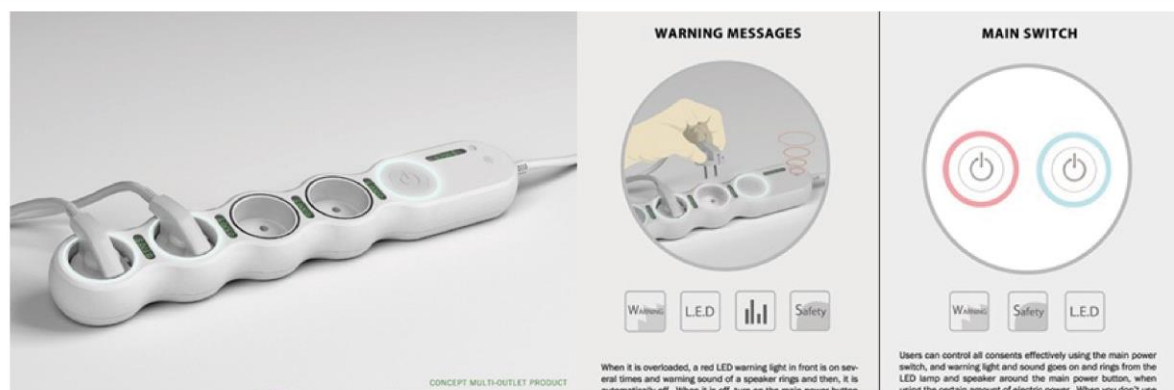
The energy saving method is one of the most significant methods to influence electronic markets and as previously referenced in section 3.2.1.3 (chapter 3), this area has had large investment, particularly in mobile phone innovation. The purpose of this method is that it leads to higher efficiency of energy consumption by understanding user behaviours, designing products that can save more power such as battery type and display size and charging behaviours.

According to figure 4.12, the energy saving method can work in three different areas; firstly this method can influence managing power consumption during manufacturing, secondly this approach may impact energy consumption during the usage of designed product shapes, systems and usability and thirdly this also works on the disposal area to manage the waste batteries and produce a disposal system that can reduce the disposal process and collection of waste energy from the terminated batteries.

However, this research is limited and has looked at Zone B, which is power consumption in usage time, because the measurable needed the same conditions, which could be analysed through LCA and also select one major period to compare each eco design method with. The energy saving method contains the most

progressive context to appeal to consumers; this method could be a more realised approach to solve energy problems rather than using alternative energy or futuristic approaches.

Although the strength of this method could also be a difficulty for industrial design compared to other areas because traditionally this area has focused on R&D and the engineering areas and apparently this area appears to be engineering and technologies oriented. However, to achieve energy saving effectively, these advanced technologies should merge with industrial design approaches that are i) developing new product schemes to change the user behaviours and ii) finding design concepts and direction to reduce energy consumption through industrial design values.



Picture 4.8 Example of the Energy saving method (Multi Saving Power Strip)

(<http://internetsiao.com/energy-saving-power-strip-with-power-meter-design/>, Access date: 20th October 2013)

This example shows how to apply the energy saving method to product development in a design perspective. This conceptual design has indicators, which signals the current status of usage for preventing waste energy consumption. This product was approached through traditional industrial design approaches such as considering usability and functional product values however, to apply the energy saving method in an industrial design perspective requires reflection on fundamental design principles, which are based on the balance of functional and emotional benefit to appeal to markets and consumers.

Summary of chapter 4

- Each eco design method has the different impacts on different sectors and these conclusions can be demonstrated by schematic approach
- The light and heavy user groups influenced to the results of eco design adoptions
- These schematic approaches only demonstrated the different rates of influence in each area of product lifespan
- Each eco design method has specific strengths and particular the product types or different conditions of markets. Selecting eco design methods can be applied to address different standards
- Energy saving method showed the most effective results in business perspective because this method can be satisfied to current consumers' functional demands and environmental requirements together

Chapter 5. Methodology

Precis of chapter 5

- Determine the way to establish the research structure, process and methods
- Combining and finding the clue from the previous research for establishing framework for understanding research implementations such as students design works, interviews, environmental evaluations and reflecting representative methods
- Establishing research hierarchy

Given the key drivers – data collation, evaluation and representation (as identified in Chapter 3) the methodology developed here will link these together to establish those approaches which best exemplify the effectiveness of eco design tools in a mobile/micro-electronics context.

The principle question when the research field was originally planned was the extent to which designers deployed eco design tools in the development of electronic products. As will be shown, an understanding was discussed and integrated throughout the organisations, with senior managers and marketers understanding the importance of eco design and fit with the eco policy, and designers lacking experience of relevant tools and processes for realising eco compliant products. This is symptomatic of the narrow role played by design in Korea, and has necessitated a re-think of the research strategy, as discussed in section 5.4.

The key sections within Chapter 5 are:

- i) A background exploration of appropriate methodologies (section 5.1)
- ii) Discussion of the research framework (derived in section 5.2) and the units of analysis

- iii) Rationale for the approaches and their sequence, used to capture data (section 5.3)
- iv) Prior research undertaken which is relevant to the study (section 5.4)
- v) Research undertaken (section 5.5)
- vi) Design of pilot experiments (section 5.5) particularly;
 - Use of a controlled design experiment
 - Evaluation methods and practical experimental structure
 - Data analysis approaches
- vii) Discussion of sample source and sizes (section 5.6)
- viii) Critical evaluation of the methods used (section 5.6)
- ix) Evaluation outcome and organisation (section 5.7)

5.1 Overview of the generic research methods

Research methods can be applied from both qualitative and quantitative perspectives. Qualitative and quantitative approaches implemented in the research can be differentiated by their different features and strengths, a qualitative perspective leads to innovative approaches and finds problems, whereas quantitative approaches undertake evaluations and are critical of research data.

The research frameworks (section 5.2) are considered from the researcher's main question – “if the tool achieved positive results for the environment such as reducing environmental impacts and energy saving then may it has advantages in the business perspective, which has developed to this research questions that are i) to establish the effectiveness of differing sustainable design approaches on the development of mobile phone and ii) to compare the results between ecological

benefits from LCA and Eco compass and make recommendations to the industry re the adoption of eco design"- is employing techniques to extract subject data ranging from the general to specific. Surveys, experiments, archival, analysis of prior research, and case study methods can be used to prove the methods appropriate, and show differentiations from a number of alternative perspectives. The choice of method however is largely dependent on the formulation and clear definition of the research questions and/or aims of the study (Robson, 1994).

The matrix overleaf is based on the strategy for methodologies in Robson research. As shown in the matrix, this research consists of practical and academic approaches. Firstly academic approaches present definitions, appropriateness, accessibility and explores environments and various approaches to solve the problems in this research. The academic approaches will be implemented at an early stage in this research, and provide guidelines for design results, which may create through undertaking the design experiment, and questionnaires for primary interviews (see appendix 1). Experimental design approaches may show i) a conceptual eco design process for designer, ii) a logical adoption method in using engineering data in design and iii) demonstrate what difficulties are in the particular sector areas and why those are not suitable for designers in solution development in relation to difficulties and barriers faced.

When planning hierarchical processes and strategically combining quantitative estimation and qualitative decoding, this suggests a possible solution for the designer in the use of eco design tools which either optimise or are more appropriate to his/her discipline. It also presents various advantages and disadvantages of eco design tools, which were applied to achieve appropriateness for eco design tools in particular industry sectors through the exploration of quantitative and qualitative approaches from the designer's perspective rather than the engineer's focus.

Strategy	Form of research questions	Require control over behavioural events	Focuses on contemporary events
Experiment	How, why	Yes	Yes
Survey	Who, what, where,	No	Yes

	how many, how much		
Archival	Who, what, where, how many, how much	No	Yes / No
History	How, why	No	No
Case study	How, why	No	Yes

Table 5.1 Research strategy, contexts and research questions (Robson, 1994)

The research outlined in this thesis adopts four major research strategies; experiments (design exercises), surveys, literature studies and case studies as used within the sciences, and based on Yin's research (Robson, 1994). This explores four areas:

- The combination of practical and academic methods for providing evidence. Eco design methods have nearly always been used in engineering areas; for simplifying manufacturing process and energy saving. However, if the methods are applied widely in the very early stages of the product development process, such as design or planning, this may stimulate effective reductions in eco impacts. Since the concept of eco design innovation has emerged, it has been highly developed in a theoretical context rather than at a practical level. This research will show how eco design methods may be used in the traditional product design area through combining academic and practical eco design methods and eco evaluation tools.

The qualitative approaches in this research, are constituted by various experiments such as LCA) evaluation, adapted Eco-compass and implemented FGI (Focus Group Interviews). Those methods that illustrate eco design processes are applied to eco design tools and evaluations. It will also show differentiations between ecological approaches and business results through FGI. The qualitative methods such as primary interviews, students design works and user behaviour surveys show the current ecological awareness of customers and may show suggestions for each practical experiment.

This approach may suggest that i) designers' have new opportunities in the eco design areas through the understanding of other sector methods such as UI(User

Interface) design, UX (User Experience) design and CMFP (Colour, Material, Finishing and Pattern) design and ii) making eco products, which have possibilities in the business by combining traditional design and new approaches.

5.2 Research framework and the units of analysis

Research has been designed based on the conceptual framework shown in fig 5.1, which includes: experiments, evaluations and user surveys in Korea, and industry surveys for designers, managers and eco design experts during the early stages of the research.

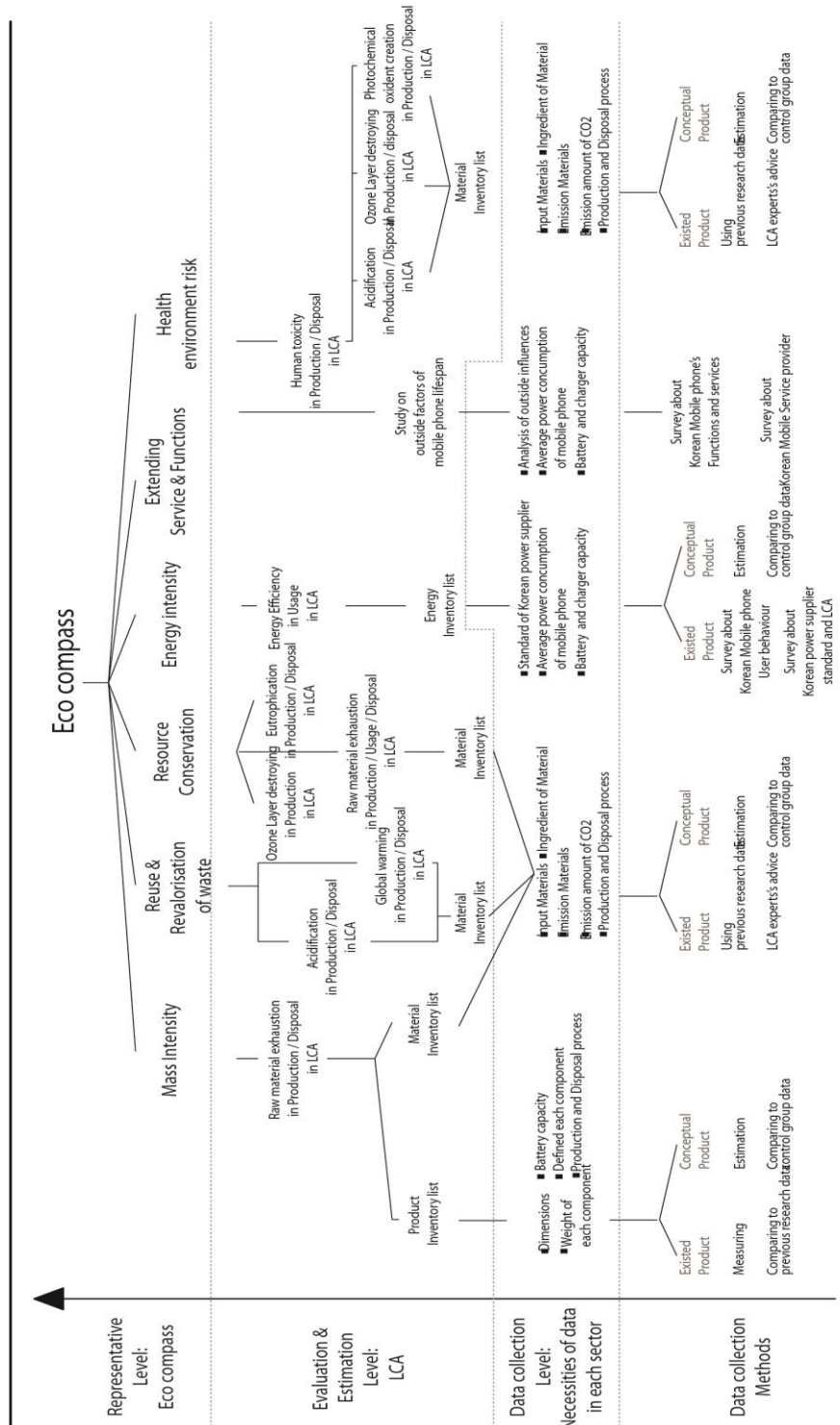


Figure 5.1 Structure of the research framework

The research framework has four different phases: representative, evaluation & estimation, data collection (finding & exploring) levels, and data collection methods in each category. Evaluation of the six factors in the Eco compass requires the use of a quantitative estimation tool such as LCA, and the use of surveys. These approaches also demand lower level activities such as the making of inventory lists and

establishing questionnaires to undertake LCA and surveys. This research structure appears to be a vertical hierarchical structure; however, to effectively complete the Eco Compass requires the sharing of background data and results at the same level as other factors.

Particularly, LCA has been the representative environmental evaluating method and using for indicate tool for quantitative measuring to environmental impacts in Korean electronic industries since 1997. According to Korean newspaper (MK business news 2nd 9. 1997), Samsung electronic achieved reduction of product components especially 33.9% of TV and 27.4% of washing machine and these achievement linked to effective time management that it saved 35.5% of total assembling and 47.9% of disassembling of TV (MK business 2nd 9 1997).

This example shows LCA has been one of the recognized methods in business area and that aspect, which has higher reliability, can be the background to adopt LCA for this research.

Most results in the Eco Compass are based on LCA; however 'extending service and functions' demands surveys of mobile phone service providers as does establishing 'energy intensity' which requires the use of surveys and interviews to understand user behaviours. These results may be used with background data, are materials, dimensions, scales, and functions of the mobile phone as well as studying energy consumption and efficiency within product life span for LCA. The six factors in the Eco Compass will be made by combining LCA, surveys and interviews, and the outcomes may effectively illustrate comparisons of the advantages and disadvantage of each eco design tool and factor.

5.3 Overview of approaches and the sequence of events

For finding and evaluating an appropriate eco design tool, this chapter shows several significant experimental steps - i) critiquing hypotheses, developing research questions and establishing research topics through interviews at different levels and different areas of worker (see chapter 7, section 7.1), ii) developing a method for trialing eco design tools (see chapter 7, section 7.2) and making standard evaluation

methods (see chapter 6), and iii) the surveying of consumer and service providers' behaviour, functionalities and product lifespan (see chapter 7, section 7.5).

Research stages and achievements

At the initial stage, when the researcher gained access to Korean electronics company employees, it became apparent through interviewing designers that such tools were neither used nor well known at a preliminary interview stage. The methodology was subsequently adapted, on the basis that the research should consider key criteria used by the mobile sector in the choice of eco-design tools, it therefore needs to provide an evaluation of the opportunities and costs afforded by each. However, it is apparent from the literature in Chapter 3 that a comparative study of such tools has not been undertaken previously, in likelihood due to the highly product-specific nature of each application.

Figure 5.2 illustrates how the research strategy has changed, as the data has been required to be captured at each stage. This research has 4 key stages, which clarify various issues and generate the required data for the subsequent analysis.

At stage one, interviews were undertaken with mobile phone manufacturers in October 2007. These interviews targeted different individual levels of authority within each organisation, ranging from CEOs to designers, and demonstrated that current eco design tools, processes and design policies were poorly implemented in those Korean mobile phone manufacturers participating. Three different questionnaires were delivered to designers, managers and eco design expert groups. More detail about samples and targets are provided in section 5.6 (see also appendix 1).

A key outcome of this was the necessity to change the research question. The primary interviews documented actual Korean electronics companies' status with respect to eco design and there were significant differentiations between what public relations claimed organisations were doing, and the reality of what eco design tools were achieving, where they were implemented. Hence, the research emphasis changed from finding instances of the use of eco design tools, which the companies

used for developing eco products, to an evaluation of the potential effectiveness of differing eco design tools within the Korean mobile phone industry and market.

At stage 2.1 in Figure 5.2, in the absence of empirical designs from industry, students undertook a design exercise using a range of eco design tools, categorised earlier in the literature review. This generated 24 design concepts via 8 differing design methods, which were subsequently rationalised down to 8 concepts.

At stage 2.2, quantitative evaluation was undertaken using LCA, production, disposal and recycling stages. This identified the advantages and weakness of each tool across the product lifespan, together with an indication of confidence levels in these figures.

At stage 2.3, a consumer survey was undertaken to establish usage patterns for each mobile design. Based on these, and estimation of total energy consumption in the usage of each design, which when factored by known LCA analysis for national power generation, usage impact was estimated at stage two of LCA analysis.

At stage 2.4, a cross comparison of the eco impact of LCA was undertaken, and results plotted on the eco compass framework proposed in chapter 4.

At stage 2.5, interviews with technical experts were undertaken to establish the viability and cost implications of implementing each of these tools in the company.

Section 2.5 comprised a discussion with CEOs, management, marketers, designers and engineers re establishing appropriate design tools, which reflect different perspective areas for the Korean mobile phone industry.



Figure 5.2 Development of the Research Methodology

Returning to the original research question, this research sought to undertake primary interviews to evaluate the initial hypothesis and to establish subjects (more detail is provided on the primary interviews in section 5.4).

Through the interview, the question was,

“What were the eco friendly design methods, which Korean mobile phone manufacturers use currently? Whether they have used eco design tools and why have they selected these tools? Or if they have not, then why have they not used them?” The researcher also looked at “What were the differentiations between public relations and realistic undertakings? What and how different were the levels of

knowledge between managers, senior managers, designers, senior designers and operators?”

The intention was to study eco friendly design methods and applied cases in the Korean mobile phone industry and research into eco friendly products via case studies. This approach had to be adapted as not many actual examples or eco experts existed and there was a large knowledge gap between managers and designers (see section 5.5). This is not perhaps surprising, given the results of a Korean Institute for Design Promotion survey (KIDP, 2008) which found that of the 100 top Korean companies, product planning departments were the highest ranked authority in decision making (45.8%), followed by new product development/R&D (42.4%), market analysts (39.4%) and marketing (37.1%). 55.6% replied that design did not participate in manufacturing, service provision or engineering.

The research question was subsequently changed to ‘finding and suggesting appropriate eco design tools against industry sectors through quantitative and qualitative evaluation – in this instance centred on the Korean mobile phone industry.

The modified hypothesis required the combination of several diverse research approaches to reveal the advantages of (and barriers to) the adoption of current eco design tools, their appropriacy for designers, and difficulties in interpretation problems between eco design tools and designers.

Each stage consisted of various experiments and surveys to test/prove the hypothesis and establishes reliability.

5.4 Approaches used by other researchers in the field

This section reviews prior research into: i) the use of approaches testing the application of eco design methods to product development; ii) guidelines in the implementation of group design exercises; and iii) the undertaking of eco design product development via eco design methods.

5.4.1 Applying qualitative eco design methods and finding guideline

Raja Ariffin (2008) applied Environmental Effect Analysis (EFA), initially developed by the Swedish Institute of Production Engineering into product developments. He thought that eco design tools are too complicated, effectively reducing their usefulness.

His tool is based on the Checklist type; for each environmental effect ratings are made on the impact itself as well as the impact of the planned corrective action to ensure improvements are made. Lofthouse (2005) also applied the Eco Design Integration Method for SMI that is currently deemed to be difficult to be managed and handle. However, results of these generated less accurate data over implementing more quantitative methods. Consequently, the researchers have considered balancing such problems against more understandable and suitable eco design and evaluation tools. In order to better understand the applicability of the tool above a set of reference is being used as listed below (Raja Ariffin et al, 2008). The references are based on the work by Lindahl (2006), Mizuki et al (1996), Baumann et al (2002) and Lofthouse (2005) .

- a) Easy to understand and experience, the benefits such tools provide include being intuitive, logical and easy to communicate that simplifies their work and benefits are realized immediately.
- b) Easy to understand how the method works; the implementation threshold must not be too high
- c) Adjustable to different context should be able to fit company culture
- d) Setup time has to be considered
- e) Not require a lot of cooperation should not require too much of simultaneous physical cooperation

- f) Not too high requirements for data
- g) Visualization of result relevant, attractive and easy to understand result visualization
- h) Provides directions that directions or indications would be the next action plan

These lists are generated by previous researchers' empirical studies. However, the eco methods, which are influenced by the lists, are only qualitative input in the form of basic product (Raja Ariffin et al, 2008). Therefore, a designer or director has to decide what use of eco design tools is made by understanding types of project and product.

From these lists, quantitative and qualitative methods have different advantages and weak points; hence, this research undertakes quantitative (LCA) – albeit as a qualitative approach - and this may provide the innovative process to solve various complexities.

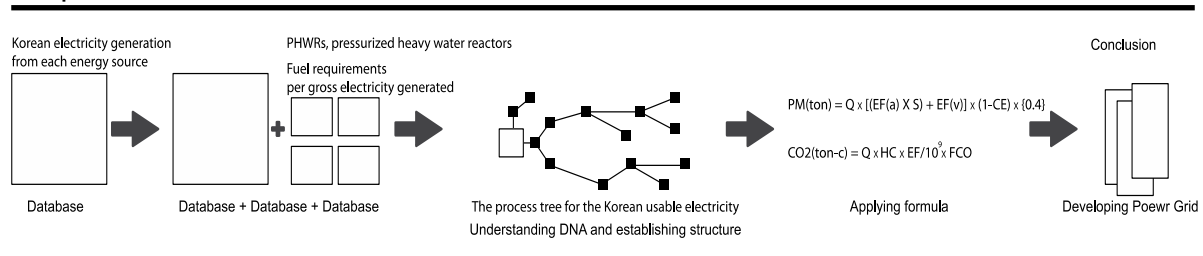


Figure 5.3 Research structure; showing an example applying LCA

This primary study provided guidelines for collecting inventory lists and analysis. Particularly this will directly help to 'Reduced Functionality' and 'Energy Saving' methods, which are focused on increasing energy efficiency in usage level and which will use in this research. However, differentiating this from the primary study, this research requires mobile phone user behaviour data to be applied to quantitative analysis to find average power consumptions in usage (see chapter 7).

This thesis has adopted the above analyzing process for particularly verified types of collecting materials and may help to calculating methods for power consumptions.

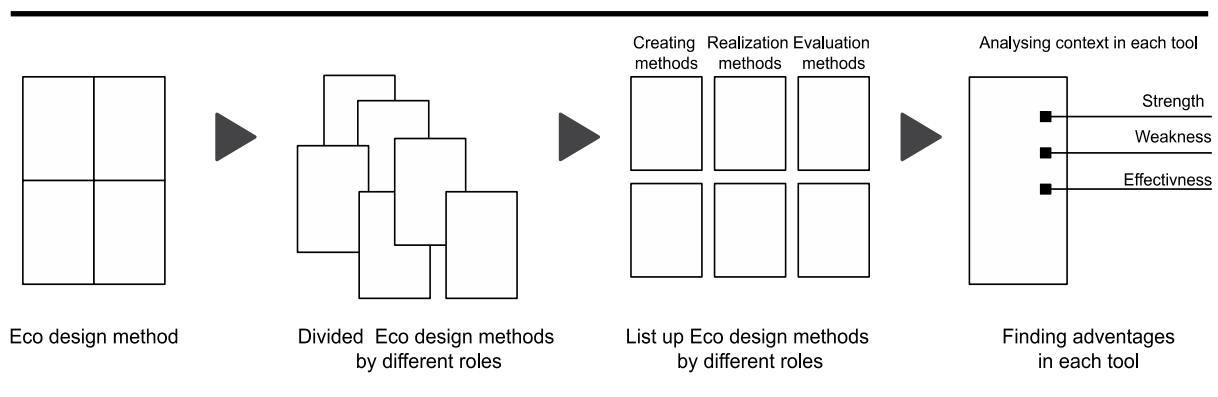


Figure 5.4 Research structure; defining the eco design tools

Figure 5.4 exemplifies how to categorize and what standards can be distinguished against eco design methods. To understand and implement further research process, this thesis also requires the grouping and categorizing of eco design methods through figure 5.4's process to effectively use eco design tools for further pilot exercises and evaluations. Therefore this thesis has established two different standards: i) by product life span and ii) different approaches of each eco design tool (see section 3.2.4).

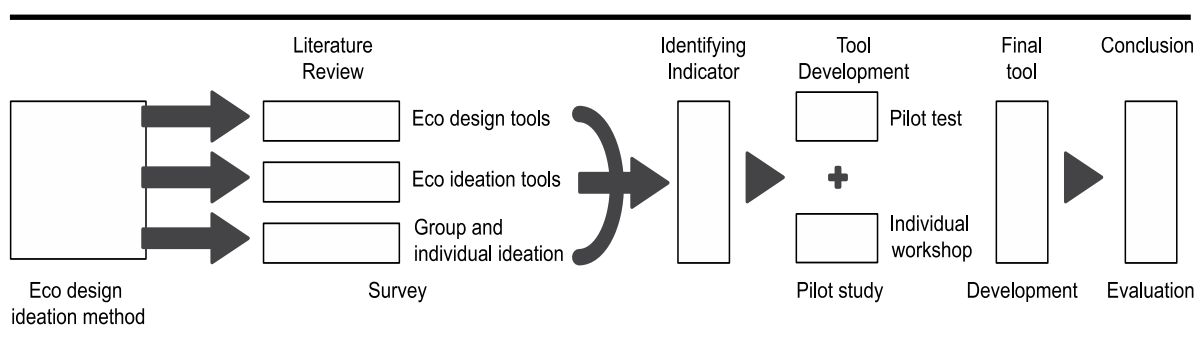


Figure 5.5 Research structure; suggesting structure for group design work

Figure 5.5 shows the process for group design work. This primary study undertook group ideation by using eco ideation methods and this process influenced evaluation and conduct approaches within the student design exercise (chapter 7). As illustrated in this figure, to generate the ideation results the researcher integrated

pilot studies and individual workshops to reduce subjectivities in the design results. In order to reduce the author's influence and bias, the student design exercise in this research has been implemented in divided locations.

5.4.2 Undertaking the Design Exercise

This section discusses prior examples of student design exercises, which provides guideline and insights.

Wallace and Blessing (2000, cited in Blessing and Chakrabari, 2009) suggest that design research is currently within an 'experimental' phase, having previously passed through an experiential phase, in which the senior designer or project director describes the key aspects of project, and an intellectual phase in which academics propose methodologies, principles and tools. Jones (2003), who studied the effectiveness of Eco-Innovation tools using engineering design experiments, conducted such studies with undergraduate engineering students.

Some of the features of this work listed up from a positivist tradition include:

- The use of a 'control group'
- The use of exactly the same design brief in both the control and experimental group
- An attempt to control for participant variable such as design experience
- And the avoidance of participation by the researcher.

These approaches estimated different types of results with this research, however above guideline provides the essential factors that applying the same conditions to each participate and avoidance of researcher participation.

Through such a design experiment approach to investigating the eco design methods, possible benefits listed by O'Hara (2010) would be:

- Improved claim to 'internal' or 'construct' validity – following a design experiment allows the researcher to draw upon a range of strategy developed within the positivist tradition for reducing bias stemming from the researcher or the participants.

- Repeatability – following a highly structured experimental protocol should enhance claims to the repeatability of the research activities.
- Acceptability of results within the research community - as mentioned previously, design research is within an ‘Experimental’ phase and hence it will be easier for the research community to evaluate the quality of the work and, all being well, accept the findings.

Equally, some of the problems of using a design experiment approach investigating the introduction of eco-innovation tools would be (O’Hara, 2010):

- Risk of Hawthorne effect – in trying to establish a controlled environment in which to perform an experiment unnatural behaviour may be elicited in the participants.
- Theory-testing not theory-building - There is relatively little existing theory on why eco-innovation tools are not adopted by design teams or how to customise eco-innovation tools. The strength of design experiments is in theory testing, not theory-building.
- Difficulty in investigating contextual factors – In the previous section it was noted that a realism viewpoint acknowledges that a mechanism may fail to activate if the contextual conditions are not appropriate. Part of the stated aim of this study is to understand what contextual factors may affect the adoption of tools. Design experiments would not be an appropriate methodology for investigating such issues.
- Reductionism not appropriate – related to the previous point, experiments, including design experiments, assume that the behaviour of a system can be explained if the behaviour of the individual parts is understood e.g. the whole is equal to the sum of its parts. However, due to the complexities of social ‘systems’, which are ‘not homogenous through time’ (Keynes 1938 cited in Checkland and Holwell, 1998), this assumption may not be valid (Checkland and Holwell, 1998). Hence the findings from testing eco-innovation tools within a design experiment in a controlled situation may not be useful in predicting the success or otherwise when the same tool is introduced to the organization as whole.

In summary, this research will not consider social issues in the student design exercise. Whilst traditional industrial design approach may not undertake market and target research, for the purposes of this research, the focus is on finding the appropriateness of eco design methods through structural exercises and evaluations. Therefore this research needs to maximally avoid external factors and generate results by qualitative evaluation.

However, using the approaches of this research in companies and product development then it requires integrating with traditional industrial design process to achieve marketability and productivities.

5.5 Methods for data gathering at each stage

Looking at section 5.2 (Research Frameworks), this research consists of four stages (Representative, Evaluation and Estimation, Data collection and Collection method level). This section will define the Collection method level, which is located at the bottom of the research framework.

5.5.1 Measuring existing models

This approach was used for making product and material inventory lists in this research. This approach measured all components of existing mobile phones regarding weight and dimensions of each component, calculating the number of components, solving assembly efficiencies, considering manufacturing and disposal processes and also studying features of materials usage.

5.5.2 Comparison between measuring data and previous research

Based on the measured data, it compares previous inventory lists and research data, which used the same or similar materials to verify the data. To gain higher reliability, the author and LCA expert (Eun Soo Kim) evaluated Korean companies, who

supported this research by advising on manufacturing and design, Companies A & C confirmed the inventory lists.

5.5.3 General user interviews for finding influencing factors for LCA within usage

The LCA in this research required data re various behaviours of energy consumption for analysing usage levels of LCA and for gaining data.

The relationship between this research and Energy consumption, it is mostly international environmental legislations, which are the most powerful influences to this research have contained or focused on how to save the energy consumption and management energy consuming. Although these aspects have used the highly effective protection approaches for advanced countries industries.

For instance, German announced new energy regulations that only under 1600 watt vacuum cleaner can be retailed and imported from September 2014. Moreover such as this energy regulation will be stronger that vacuum cleaner can be selling under 900 watt from 2017. According to EU, the aim of this regulation will entire energy consuming by reducing amount of individual home energy consuming (ETnews 01, 2014). Such as these global concerns about energy consumption could be the significant outside influence to this research and especially energy indicate will provide the quantitative background data for LCA for the mobile phone.

The author undertook general interviews regarding the mobile phone users in Korea (see chapter 7). The targets for the interviews were from teenagers to seventy year olds and were divided into groups by age, occupation and gender by demographic standards. The key purpose of these interviews was to find the average operating and charging time and patterns of mobile phone behaviour and influencing factors on purchasing decisions.

5.6 Implementing data collection

5.6.1 Undertaking experts interview for the primary research

The expert interviews were based on designers and marketers, and the Korean eco experts provided background knowledge to establish the research questions and

focus. The interview had two different targets; one was focused on large companies and designers and the second was focused on the Korean eco experts. Each interview took between 30minutes and 1 hour to complete. Companies, who were selected for this interview, were the top sellers and producers in the Korean mobile phone market. The other significant choice for selection is that they have to export over 60% of their mobile phones to adhere to domestic and international eco regulations.

For this interview, only Company A permitted a meeting with design decision makers, marketing and sales personnel, and both Company B and Company C brought different roles and levels of designers to the expert interviews.

Number of respondents	Level of departments	Major role
11 / 15	2 decision makers	Design decision / Management Building design directions
	3 senior designers	Design decision / Management
	2 operators	3D graphics / Art works
	2 sales man	Merchandising
	2 marketers	Market analysis / Building strategies

Table 5.2 Primary interview target _ Company A

Number of respondents	Level of departments	Major role
6 / 6	3 senior designers	Design decision / Management
	3 Junior designers	Design works

Table 5.3 Primary interview target _ Company B

Number of respondents	Level of departments	Major role
5 / 5	1 senior designers	Design decision / Management / Strategy
	4 Junior designers	Design works

Table 5.4 Primary interview target _ Company C

The author undertook expert interviews with 3 Korean eco experts; Prof. Ho Sup Yoon, (responsible for introducing eco design theory with Korea in the 1980's); an environmental analyst, Eun Soo Kim, from Su Won University, and the eco designer, Kyung Ah Kim from Seoul National University.

During the interviews for the primary research, survey limitations occurred in different areas of interest. Firstly there was a communication problem internally between marketers and engineers. This occurred because i) the researcher had only design experience and worked in the design department and ii) designers lacked inter-departmental communication skills. It was also evident that higher level staff such as office managers or head officers had a greater understanding of their company eco policies and eco tools, which were based on sigma 6, & not design focused. However, most designers and operators did not know their eco policies or the importance of eco product development. Lastly, to achieve higher quality from further research, government and policy makers who produce national eco policies ought to have been interviewed. This however was very difficult as Korea is a very hierarchical country, and the government will not enter into individual research projects.

5.6.2 Undertaking objective evaluation of the efficacy of Eco-Design tools via students exercises

Various pilot studies and experiments have been undertaken to establish research purpose and verify the hypothesis in this research. The survey undertook literature reviews and 3 sets of interviews at different research stages. In developing this evidence base and background data, the author undertook 3 experiments: undertaking eco design, applying evaluation methods, and decoding data.

A key feature of the approach used was the adaptation of exploratory approaches - such as DfD, reduced function and anti fashion - in the pilot studies (shown to the left hand side of figure 5.2) to determine the characteristics of each tool (see chapter 3), particularly re the discrete limitations and implications, made necessary by the lack

of reported mobile (or other) cases in which such tools have been trialled. This element of the study is not intended as an objective study of the relevance and impact of each tool in isolation, but as a comparison; importantly it is to provide an indication of their utility and the possibilities generated by each within the mobile design context, thus allowing each of the participating organisations (Company B, Company A and Company C / Kookmin and Suwon universities) to evaluate discrete approaches, the extent of synergy (or otherwise) with existing processes and their net contribution to the eco-rating of the company's product range.

In common with other exploratory approaches, the pilot study – undertaken by undergraduate design students at Kookmin University - set out to investigate the (causal) relationship between benefit and cost within each approach. Students were arranged into eight groups of 3 students, mixing upper and lower quartile students to ensure consistency in ability.

This approach involved the development of a range of mobile phone design concepts against a set brief, employing each of the tools in isolation, as a control variable. For those reasons, it has not been possible to undertake this within a field setting, and as such the exercise has been restricted to the classroom- Participations were organized into eight test groups, each group consisting of 4th and 2nd year students. Most of the 4th year students had a mix of design internship experiences in the design field, and understood environmentally friendly design tools. Methods were taught to each group to increase the use of their level of understanding and to reduce the incidence of similar designs, under the supervision of design tutors with experience of the sector and such tools (see chapter 7).

- System for pilot study and evaluations

During these experiments, Kookmin university PhD and MA students joined the program as observers. The reason of involve MA students have academic experiences for research management and implementations and also MA students have strategic research management therefore this group took the role to manage BA student for effective research undertaken.

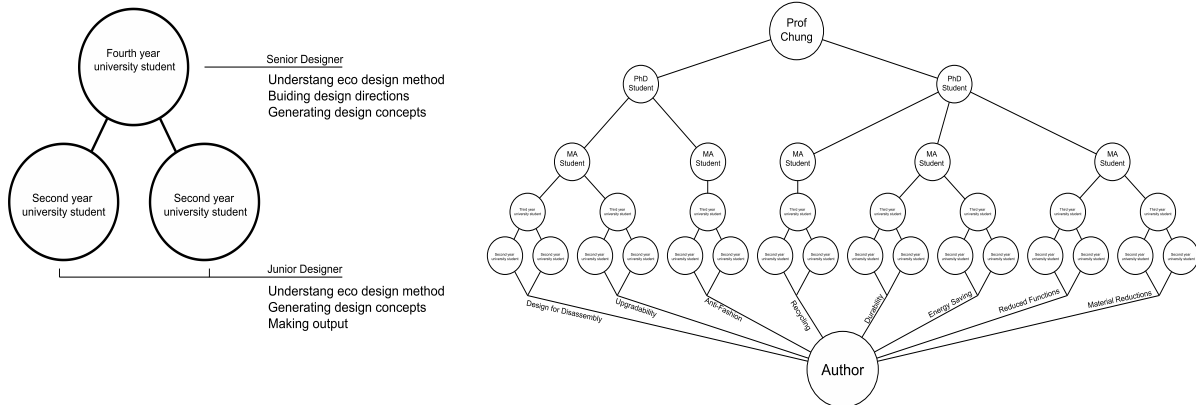


Figure 5.6 Structure of student design pilot study

Before applying the eco design tools to the products the author prepared different scenarios and tasks, which helped the students to understand the advantages and strengths of each tool using different rooms for each student team to undertake said exercises. Each group participated using only one eco design tool, and the results were collated based on comparing differing approaches.

Masters students managed two teams within this experiment but two teams, undertaking Anti-Fashion and Recycling methods needed one to one supervision, as these approaches were significantly more complex. The Anti-Fashion methods group had to derive emotionally sustainable consumer satisfaction. In the case of Recycling, methods could not be accomplished by using only a single product but needed structural approaches and an understanding of national recycling policies. The role of the author was focused on directing students to apply the eco design tools appropriately rather than evaluating design completeness. Each result showed outcomes that demonstrated both advantages and disadvantages for the qualitative and qualitative evaluations.

Prof. Chung and the author evaluated their work through the evaluation table (see table 5.7), which focused on 5 key issues. Each category has five points for evaluating the ranges; from 1 (poor) to 5 (excellent). This evaluation method was developed through the advice of Prof. Chung and Mr. Noh who was head of design

department in Company A and participated in primary interviews for the research, also creating design evaluations in the companies based on general industry. However, company evaluation tools are widely reflected developed companies cultural aspects and more focused on manufacturing and profit.

- Design validity

This involved evaluating the validity of housing design but also estimating realisation. Eco design tools were applied to the products, but designers were unaccustomed to these design methods. Design validity reflects various fundamental product design values, such as producability and marketability.

- Understanding of eco design tools

This sought to evaluate students' understanding of eco design methods and ability to apply them to the products effectively. This was the most significant factor and each design result showed the effect of using different eco design methods.

- Effectiveness of applying eco design

This evaluated the effectiveness of ecological, functional, emotional and aesthetical application. Therefore, deciding and selecting the eco design tools for the design object is a significant factor to generate effective design outcome.

- Value of design work (Differentiation factors with current mobile phones)

This evaluated product values. Not only did this evaluate design values but it led to the fulfillment of the eco standards.

- Possibility of realisation

This evaluated manufacturing realisations. It also provided a range of design. Product design often creates imagination but this research needed to compare design results to existing mobile phones under similar conditions.

Categories / Point	1	2	3	4	5
Design validity	•				
Understanding eco design tools			•		
Effectiveness of applying eco design					•
Value of design works			•		
Possibility of realizations					•

Table 5.5 Example evaluation matrix for student pilot studies

This indicator has 1 to 5 points (1: very weak / 2: weak / 3: moderate / 4: strong / 5: very strong).

The design work or designers often creates conflict with others particularly in the communicational and interpreting aspects when they need to adopt different sector theories. In this instance the author prepared two special design sheets (see appendix 1.2); one was for developing design concepts and the other was a current mobile phone comparison. For the extended design concept this uses line drawing and abstract lines which means there are no aesthetic or additional functions. The second paper used standard (2009) mobile phone silhouettes, allowing comparison of LCD size, buttons, housing and battery, allowing use of an inventory list to carry out LCA at a later stage. Each team created more than 3 ideas and Prof. Chung and the author selected one idea from each team.

After the experiment the author interviewed the team to understand the difficulties in using each eco design tool. The contexts for the interviews were focused on the possibility of using such tools in the design area and understanding the designer's capability to learn the eco design methods. The conceptual framework of eco design tools shows which approaches are better for designers; such as functional, emotional, structural or even interactional.

- Guideline for the pilot study

The student exercise, it required the several different approaches. The approaches were i) the design approach which is focused on qualitative results, ii) eco design approaches are considered in a particular area, extending the product life span,

assembling processes or reducing the production and disposal process. There are different issues with traditional product design approaches, which concentrate on changing shapes and realising new functionality. iii) Most eco design tools are developed for engineering functions therefore it demanded the author understand and translate this effectively for realising design.

- Finding an appropriate Korean university for the research

There were effective student experiments carried out in three major Korean design universities who used candidates for the student experiments; these were Kookmin, Seoul and Hong-ik universities. Doctor Kyung Ah Lee who was a manager in the eco research lab in Seoul national university advised on the best university for the experiment during the primary interview and Kookmin University, which could provide design results in the very short term was selected. Contact was officially established through Prof Do Sung Chung, head of the faculty, who had significant experience of eco design, having undertaken national eco friendly projects as a product designer helped this research.

Kookmin university; i) currently this university has one of the highest ranked educational reputations in Korea, ii) the curriculum was very focused on practical design, iii) they trained the largest amount and highest quality designers in large sized companies iv) they provided several rooms for this research, v) most students wanted to enter product manufacturers such as Company B, COMPANY A and Hyundai, therefore the students have various work experience – particularly 4th year students who mostly have more than six months work experience.

In summary, the author decided that this university was the optimal place to secure the appropriate participants and using separated rooms to do the experiment. It is worth noticing that the author undertook very similar experiments in several other Korean universities which generated similar experimental concepts in 2011. Comparing Kookmin University results with those generated elsewhere, there were similar quantities of idea generation. However, the quality of design created at different levels in Kookmin University is significantly more realisable.

5.6.3 Undertaking Surveys for Korean mobile phone service provider understanding

The analysis steps of this research are based on product lifespan. This chapter implements analysis on the Korean mobile phone service providers, who can impact on product lifespan directly and indirectly and this will provide the reasons for changing outside factors.

- Survey re the Korean mobile phone contract policy

For this investigation, the author undertook analysis within the mobile phone contract of SKT (SK Telecom) who are the largest mobile phone service provider in Korea. The importance of this analysis will show the validity for the change required and how and what impacts have the consumer's decisions uncovered.

Firstly the implementation of SKT mobile phone contract and the critical standards were divided into two factors; one is various options and the other is essential factors. The most significant essential factor is the term of contract and this can highly impact the product lifespan. Secondly, the author needed to know the guidelines regarding the use of mobile phones. In Korea, when the new customer signs the contract, there are several agreements for using personal information for marketing. These often influence the frequency of consumption (see chapter 8).

Thirdly, analysis of tangible advantages and potential disadvantages occurred when the consumer changed mobile phone providers. These circumstances started in the marketing area and provided very visible and short advantages. Major targets were mostly the young or female consumers who do not have enough income or IT product knowledge.

- Findings: what impacts the environment directly and indirectly

One could assume that changing mobile phones frequency means changing mobile phone service providers. Findings also show the relationship between the reasons for changing mobile phone and the demands of the service provider through the interviews, both in general consumers and for the focus group.

5.6.4 Undertaking interview on mobile phone user behaviour

In understanding energy consumption usage levels the author carried out a survey on mobile phone behaviour and eco friendly awareness. The major interview targets were people in their 20's which included university students and new employees and compared these to groups in their 30's, 40's 50's and 60's (more detail in chapter 7). The research method used was a sample survey with 188 samples answered and returned. Interview will have between 180 and 200 targets and to determine potential mobile phone user behaviour the researcher will implement user interviews, FGI and survey to mobile phone service providers. These all research activities will provide the differentiations by between users' behaviours, experts' opinions and sales perspectives.

- Understanding Korean mobile phone users' behaviour

To undertake LCA during the use, it required the understanding of mobile phone user's usage behaviour therefore the researcher undertook general user interviews in Korea. The interview questions consisted of three areas i) purchase intentions regarding major motivations for the buying decisions and factors considered before making the purchase, ii) usage behaviours, finding average usage periods and charging frequency of the mobile phone and iii) what factors influenced product lifespan to change mobile phones what is the average phone usage (see chapter 7).

- Difficulties during the consumer interviews

There was a lack of user behaviour data at this stage as this was not seen as a priority subject area so the research could not apply a full size survey such as with UX design. Hence, task research or persona research, which are professional UX approaches could also not apply to this particular research. However, the researcher has the UX design experiences for several large Korean and Chinese companies from 2009, so questionnaires and interview plans were based on this research. Analysis of the user behaviours may be shown by Physical User Interface (PUI) flow chart types (see appendix).

5.6.5 Finding business possibilities through different perspectives of business

The researcher implemented FGI – Focus Group Interview: Definition of FGI is one of marketing method for collecting the data and finding invisible issues that collecting 6 to 12 experts or particular targets and moderator proceeds the discussion by strategic contents. This method is quantitative method that is focused on targets' insight rather than more looking at numbers and measurements (Sergio Zyman, 2000) - with the purpose of carrying out interviews to establish the differentiation between environmental and business contexts. Hypothetically, the best eco design tools may establish the best results for the environment however manufacturers or product providers may not accept the methods and the tools cannot be defined as the most effective design method. Therefore, evidence may emerge from marketers, engineers, designers, C.E.Os and consumer groups joined DESIGNNEXT, which is the Korean design company who provided interview rooms and facilities (see chapter 8).

- Summary of FGI

Analysing user behaviours are normally undertaken using UX (User experience) or UI (User Interface) analysis. In the case of UX, it investigates consumer's fulfillments of products or the rate of errors occurring by undertaking in-depth surveys and sample surveys and using this research to understand the user behaviour, particularly the frequency and consumer use. After understanding these factors, the research applied FGI (Focus Group Interview) method, which is a representative solution in UX design for finding various problems during the usage. The author then found various factors to decide heavy or light use.

Industrial designers (senior / operator level), eco experts (LCA analyst), heavy and light mobile phone users (see chapter 7) undertook FGI. For FGI, the Korean design company named DESIGNNEXT, who provided designers and accommodation. Heavy users of the mobile phone used their phones at least 3 times more than the light user group and the most distinguishing factors were that they used other additional functions such as Internet access and camera (more information in

chapter 8). The information regarding mobile phone usage behaviour was uncovered in the general interviews.

Difficulties during the Focus Group Interview

According Marketing principle (2004), to undertake FGI requires objective interview targets, common subject, which targets need to understand in own parts and understanding the languages in different sectors (Kwang Ho An, 2004).

The significant points in the FGI was selecting and finding appropriate members. Designers, eco experts, heavy and light users of phones were combined for this research. The difficulties of FGI were scheduling the management and finding common subject areas for usage data for mobile phones. FGI was mostly undertaken by Korean engineering eco experts who had little knowledge regarding design, therefore communication problems occurred between the designer's emotional and the engineer's technological approaches.

5.7 Undertaking analysis and represent results by LCA and the Eco Compass

5.7.1 Implementing LCA in this research

5.7.1.1 Purpose of LCA analysis

Significant analyses in this research used LCA, Eco-compass and energy consumption which have a different purposes within this research; LCA evaluated potential eco impacts during producing, usage and disposal. However LCA results data is too complicated to apply to the design directly therefore, Eco-compass, which is a qualitative translating method for LCA decoded LCA data to convert to more graphical data.

The environmental impact of each tool on each set of values has subsequently been evaluated via LCA, undertaken with the support of the Environmental Engineering Lab at the University of Su-Won, Korea, using Simapro6 and Gabi4 databases, in fulfilment of Aim (i).

Both programs analyse databases to do LCA and determine both LCA rating. The GUI interface of Simapro6 consists more intuitively compared to Gabi4, therefore Simapro6 has been widely used. However, Gabi4 can estimate the relationships between cost and potential eco effectiveness. It also has different user types, Gabi4 is based on numerical value input but Simapro 6 is more focused on manufacturing and disposal processes so it uses flow charts directly from the program (more detailed information in chapter 8).

Full scale LCA, which was used in this research is the one of the most quantitative eco evaluation tools currently and has only used existing accurate data for the inventory lists. However LCA in this research implemented one existing mobile phone as the control model using the LCA data from this to establish eight conceptual design models' data, establishing inventory lists for the eight different design concepts.

To maintain objectivity, inventory lists (see appendix 1.2) for the design models were developed using several requirements. i) data previously developed by designers and LCA experts ii) based on the existed inventory lists, which was used as the control model and iii) all design models were adjusted to the same dimension and scale. However some design tools were made by considering the amount of input material per unit, such as reduced material which focused on the reduction of the amount of material and decreasing scales. These also applied to the original inventory lists for alternative materials such as rubber for the durability method. LCA can add and subtract points for each category therefore LCA experts developed limitation values on the advantages and disadvantages of each tool.

LCA may not work as a quantitative method however this can provide a comparative method, which demonstrated the designer's difficulties between engineering and design tools. Such as these difficulties are oriented from traditional discord structure that are i) interpreting problems by using different language between designer and engineer, ii) lack of understanding difficulties in coming from own areas and iii) discord structure from qualitative and emotional designer's approach versus engineer's quantitative and rational structure.

Through this experiment, the eco design tools could be divided into two parts by way of approach, which was adopted and suitable for the designers and the others were problematic (see chapter 3). The tools are specifically focused on leading user behaviours or consumer's insights, which was more difficult and are based on emotional approaches to design outside exterior product shape or the re-structuring of product functions. On the other hand, some tools could provide design motivations through the use of the tools with clear guidelines because generally product design approaches are focused on very qualitative methods at its concept generation level.

5.7.1.2 Undertaking LCA in this research; process of LCA in this research

LCA analysis has 8 stages; establishing hypotheses, literature reviews, selecting programs, making inventory lists, undertaking LCA, undertaking LCA to eco design results, comparison and outcomes (comparing current mobile phones to design results) and conclusions.

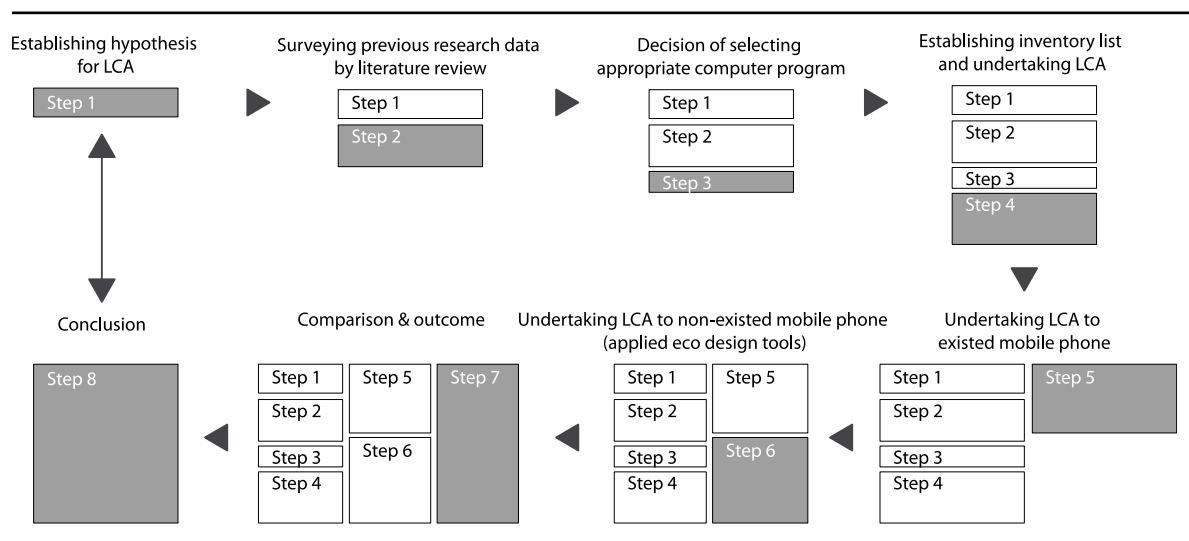


Figure 5.7 implementation steps and achievements of LCA

Stage 1: Establishing the hypothesis for LCA

Recently LCA became one of the most popular tools in manufacturing and the eco industry. This tool uses an objective evaluating approach to give quantitative results.

In 1995, Sony applied LCA to the products and they promoted their CSR (Corporate Social Responsibility) report which influenced large companies such as Company B and Electrolux to use LCA as well.

Generally LCA is focused on evaluating existing products in various quantitative and specialised perspectives. However this research needed to evaluate existing products as well as conceptual design products, therefore the author developed hypothetical inventory lists based on existing products. This work demanded ecological and technical knowledge of LCA, so the LCA Research lab of Environmental Impact in Suwon University, helped evaluate and build inventory lists. To implement the research, it requires comparable data before undertaking LCA to eco design methods. Therefore established hypothetical LCA results in this step, can be compared to manufactures eco policy and manufacturing technical capabilities.

Stage 2: Surveying previous research data by literature review

Since LCA became a popular tool, many eco experts and researchers have used it to evaluate products with social environmental problems, such as biomass production process and personal eco footprints, etc. Therefore to develop a method to apply, evaluate and decode LCA for this research, the survey needed to undertake a wide range of criteria.

Second step is mostly undertaken by literature review and this step provides guideline such as difficulties and key points for undertaking effective LCA.

Stage 3: Decision for selecting an appropriate computer program

Currently the most popular LCA computer programs are GABI 3 and SIMMA PRO 6. LCA experts who joined the author's research project recommended SIMMA PRO 6 because the program is more focused on material rather than manufacturing processes. The focus of the author's research uses the same manufacturing processes but has an understanding of the differentiations in the manufacturing processes making this very difficult. In summary, the author decided that the research perspective concentrates more on the materials used at the production stage.

This step is for selecting and finding appropriate program with considering how coincide with the objects of this research.

Stage 4: Establishing inventory lists (see appendix 1.2) and undertaking LCA

Current mobile phone inventory lists previously developed in research and with LCA experts is supported. Generally LCA covers early stage through to disposal stage. However, in this research, LCA was only focused on the amount of CO₂ emission and materials used in the production processes and the eco impact on the disposal. (Manufacturing processes are the highest enterprise security).

This step is collecting background data for undertaking LCA and building inventory list therefore this step spends the longest time and significantly hard to get the data.

Stage 5: Undertaking LCA on existing mobile phones

When using inventory lists at Suwon University Research Laboratory the author undertook LCA on existing mobile phones. It took the author one year and was only focused on material, and input and output for CO₂ emissions. This LCA is calculated on the production and disposal level however collecting resources, shipping, product usage data and rusty material was not included within this LCA.

To undertake LCA, the author needed to make additions and deduct points for different eco methods. Therefore with the eco experts the author found additional inventory lists, which students applied to alternative materials and eco impact lists. This LCA used a full version of quantitative evaluation, however it needed additional experiments due to non-existing products and several issues were ruled out of the evaluations.

This step is for building quantitative data that calculate amount of CO₂ emission and environmental impacts by materials of current mobile phone to compare with eco design methods data.

Stage 6: Undertaking LCA for design analysis

Undertaking LCA with conceptual mobile phones (using applied eco design tools) there were 8 design results, which gained the highest point from 24 design results by student work undertaking LCA. Although doing LCA to 24 models would generate better comparative data, it is very time consuming and expensive. Conceptual parts lists were based on existing mobile phone inventory data and needed additional points in specific areas for example, with applied DfD (Design for Disassembly) method could be reduced to input materials by a more simplified manufacturing process than it currently uses. Therefore, LCA experts and the author calculated adjacent measuring points, with each impact using an amount of material with a CO₂ emission reduction.

Stage 7: Comparisons and outcomes

The author undertook comparison analysis between existing products and eco conceptual design work. The evaluation by quantitative and qualitative standards of product values for existing eco design products, which are applied to eco design tools, can be realised as design tools but may work as theoretical tools.

LCA was carried out on student design work which only focussed on production and disposal level, which were not the same as general analysis therefore the research needed other analysis, which compares energy consumption, mobile phone usage and usage behaviour and the conditions from Korean mobile phone service providers for usage levels.

Quantitative indices through LCA were made during the student exploratory phase in this research which shows environmental impacts on the 7 categories, which are raw material exhaustion, global warming, Ozone layer destruction, photochemical oxidant creation, acidification, eutrophication and human toxicity (See appendix 1).

Stage 8: Conclusions

LCA for this research was focused on materials and CO₂ emission so it could make observational errors when applied to each eco tool. It also needs further research for measuring the shipping process and collecting resources to complete full LCA

analysis, however during the PhD research, the undertaking of full LCA was very costly and also companies did not disclose all of their sensitive technologies and manufacturing processes.

During this evaluation, the design area and eco engineering cooperated on multidisciplinary ideas. In Chapter 3, much LCA research has been undertaken since the 1990's however, limited research has been undertaken in the design area and moreover it is very difficult to find any examples of combinations between quantitative eco evaluation data and qualitative visual materials.

The quantitative and qualitative eco evaluations to establish the eco products are one of the key aspects in the eco design tools. Definitions and detailed information about quantitative and qualitative evaluations are in chapter 3. The approach to quantitative evaluation adopted in this research represents two valuable attempts to i) evaluate previously non-existent data and ii) evaluate quantitative design approaches. Normally, quantitative evaluation is undertaken on existing products or data; however, this research has used it to attain virtual data, based on the outcome of the student design experiments.

In terms of quantitative evaluation tools, this research used full-scale LCA, which has high reliability re accuracy and is the most popular method according to the survey in chapter 3. To undertake LCA, it requires a specially dedicated computer program and expert knowledge of these is required; hence, Suwon University in Korea was invited to participate in this research, as they had the expertise and the software.

Generally there are three different kinds of research lab for undertaking LCA in Korea. Firstly, eco expert companies, which undertake LCA and evaluate potential eco impacts regularly. It could also provide very accurate data and a wide range of information but there is a high cost so it has normally been used to evaluate eco impacts within large sized companies or in government departments. Secondly, there are the affiliated government laboratories. The Korean Ministry of the Environment operates a research lab and has evaluated potential eco national impacts. Finally the research labs affiliated to Suwon and Kunkook universities have such LCA research centres. Researcher Eun soo Kim, who worked in the LCA

research centre at Suwon university provided access to facilities such as SimmaPro 6 to undertake LCA. To do this Eun soo Kim and the author made inventory lists and LCA guidelines regarding current mobile phones.

- Applying LCA to calculate power consumption and usage levels

This stage shows the amount of energy consumption in particular products. It needed to collect data for the amounts of generation and consumption of electrical power in Korea and also the required amount of consumption for the power supplier. For understanding these, the author used various research journals and publications as references.

For this survey, background research was undertaken through literature reviews. Generally LCA has used for analysing national energy consumption and in particular products, which need to be exported or attain eco certification. This report quoted basic data from eco engineering journals and reports and publications from the Korean Electrical Power Corporation.

Measuring approach for calculating energy consumption

Looking at section 5.2, for calculating power consumption may demonstrate efficiency against the rate of waste power during usage and charging. Differentiations in LCA between manufacturing & disposal and usage in these two stages are more focused on the processes and materials rather than power consumption hence, the results of usage level may have different types of categories.

- Using LCA in the design area; difficulties against potential benefits

LCA, used in this research demanded a high level of knowledge so it was very difficult to completely understand full scale LCA in the short term period. However after undertaking LCA analysis training from the experts, analysis was carried out and the author experienced communication difficulties with designers and complications with the analysis process. It was also difficult to make inventory lists, which are used for essential background data for the LCA process for designers. Therefore for this research, the author needed collaborators to help develop inventory lists in the initial stages. The inventory list data included core technologies and manufacturing processes so it was very difficult to collect this information to PhD

research level. It required additional tools for decoding and analysing the results because the LCA results are mostly numerical values or graphs, which are very difficult to translate directly into design.

To undertake the research the author found collaborators, who use the LCA process and helped the author develop inventory lists. The author also needed to find environmental research labs and organisations where evaluation would be possible. Eunu soo Kim, who worked at Suwon University joined this research and the author spent 1 month carrying out this evaluation.

5.7.2 Undertaking Eco compass for representing the quantitative types of results

5.7.2.1 Purpose of applying the Eco compass

LCA results in this research may not be suitable for the designer because it is based on mathematical formulae for calculating production waste, disposal costs and amounts of CO₂ emission values. Therefore, it needs other tools for decoding quantitative data to qualitative data and to Eco compass, which decodes the visualisation undertaken in this research.

- Adopting Eco compass

LCA data was applied to Eco compass and then found effectiveness of eco design tools and compared this to existing mobile phone data in 6 different categories. This tool can also gauge the minimum potential eco impacts similar to existing models, whilst maximising the reductions in eco impacts to the maximum, is reduced eco impact. This visualising decoding tool can be used in qualitative areas such as design and marketing.

The appropriateness of the qualitative decoding tool is dependent on its possibility to incorporate LCA results. The Eco compass uses radar type analysis, therefore enabling a more visual tool comparison against the Eco Checklist. This also uses LCA results, which are very accurate quantitative measurements within six analysing indices so it can also undertake technical analysis.

Furthermore, the Eco compass shows potential environment impacts and can estimate the results it attains to maximise the levels of eco design tools.

- Eco design indices for Designers

Generally eco design methods have been evaluation approaches used by engineers in product developments. Mostly eco design tools have two different types of approaches: one is for evaluating by a quantitative or qualitative approach, and the other is for creating a conceptual framework or realisation for engineering. However designers have usually used qualitative materials such as images, diagrams and other visualised data. The Eco Compass and Eco Matrix are the most representative tools for solving these types of problems (see Chapter 3).

As indicated in chapter 3, quantitative evaluation tools have some difficulties, designers find it difficult to adapt to the difficult terms and symbols used. Despite these problems, many companies have still used LCA to evaluate their products as comparable quantitative tools are problematic with less accuracy. These examples might provide significant reasons to select the tool for gathering correct data and this data provides distinctions for each tool. To use LCA, this research needs qualitative decoding and translating tools undertaking the LCA (see section 3.1 and 3.2).

Many current research reports and journals have shown various obstacles to their use and there has been an increased importance and necessity for the use of decoding tools.

- Applying quantitative data by LCA to Eco compass in this research

The LCA analysis has only concentrated on levels of production and disposal and the decoded Eco compass diagram showed various changeable results in those areas rather than usage and recycling levels. Through this, visual results have been established for amounts of used materials and CO₂ emissions during manufacturing and disposal in the product lifespan. However service values and resource values in Eco compass were replaced by energy consumption levels and user behaviour within mobile phone usage and impacts from consumers from the demands of

service providers. Those areas were studied through interview, the analysis of energy consumptions and service provider's customer requirements and also observations of mobile phone user behaviour. To study on different behaviour of using energy consumption the researcher defined types of using behaviour and applied to these groups to the research frameworks (see chapter 4). To define the different aspect of environmental effects, this requires the standards and quantitative importance rate for measuring these wide ranges of environmental impacts in product lifespan. The researcher will provide the indicator to make the measurable standards with centre of weight by public confidence for calculating different aspects of environmental impacts (see chapter 8).

LCA provides opportunities for the author with industrial design expertise to experience the communication difficulties between designers and engineers, and through this it was possible to better understand those methods to use for environmental approaches.

- Difficulties when using Eco compass in this research

When using quantitative evaluation such as LCA, which was an essential analysis tool for this research, the results had to be decoded for designers. The most difficult stage was calculating the energy consumption in the Eco compass, which needed to analyse the user behaviours and usage levels for undertaking LCA. However, it required much cost and effort. Research into energy consumption was undertaken in an alternative way, which surveyed mobile phone service providers, throughout general interviews and FGI. To sum up, Eco compass was applied to the interview results to evaluate energy consumption rather than using LCA analysis.

- Summary

This evaluation demonstrated the suitability of applying Eco compass (see chapter 3). Translating from quantitative data to qualitative results can simplify understanding the resources required for designers and those issues are one of the solutions to resolve the communication problems.

Eco compass is one of the most effective and representative tools for visualising quantitative results. This researcher has tried to applied other methods such as Eco checklist however Eco compass is easier to illustrate to visualise LCA data and showing each category makes comparable graphic.

The research showed that were comparisons analyzing to each eco design tool results, way to translate from quantitative measuring to qualitative visualizations and finding eco design tools for designers through this process.

5.8 Organisation and outcomes

To undertake each research stage required different resources and data for the academic and practical experiments, studies, surveys, and interviews.

- Establish hypothesis: Survey history of eco design by the roadmap method

Before the research was initiated, the major questions posed by the author were: ‘will future eco design affect marketability and productivity?’ and ‘what is the current eco design approach in the business field?’ To understand these questions, the author compared analysis of CSR (company social responsibility) reports of global manufacturing company’s eco policies from Korea, Japan and China and using these results, the researcher developed an eco design road map (see appendix 2).

- Introductory level of research:

Primary interviews / Literature reviews on general eco design

The author undertook the primary interviews, for verification of the initial hypothesis, which demonstrated that there were gaps between the hypothesis and the business field therefore, the author needed to re-establish the hypothesis and research focus.

Organisation:

As demonstrated in section 5.6, the purpose of primary interviews was to find different levels of understanding regarding eco design tools and make comparisons with design and marketing, gain academic and business perspectives and managers and operators perspectives.

To organise the interviews, the author used three different levels of contact approaches; i) personal networks, ii) direct contact with the person who might be interested in the research and iii) contact to companies (however this was very difficult to achieve as it took much time and official confirmations).

Outcome:

Through the primary interviews, the author found that currently many Korean manufacturing companies recognised the importance of eco design and eco industries however there are organisations in the industry that are unaware of eco design and some industries have only used eco designs and eco policies as 'Green washing (see the definition in chapter 3)'. It was also seen that there were huge knowledge gaps between managers and designers (see chapter 7).

- Experiment Implementation and establishing the factors: Student experiment

To implement an effective eco design experiment, it required appropriate design students, who have previous work and research experience coupled with practical design abilities. The author selected three Korean universities; Seoul national, Hong-ik and Kookmin University, who were ranked the highest in the Korean design university evaluations.

Organisation:

Conditions for this experiment were; i) design quality and knowledge of the participants, ii) solitary testing areas / rooms for design and learning and iii) appraisers; who were design professors, Ph.D students and design students. Kookmin University followed the previous conditions and the author contacted the industrial design faculty to request these requirements. The author also carried out the eco design seminar at Kookmin University.

Outcome:

The experiment produced 24 initial design results and an evaluation matrix using 8 final design results, which were applied to the eco design methods (see more detail in chapter 7 and appendix).

- Evaluation and providing evidence

LCA / Eco-compass / user behaviour interviews

One of the key contexts in this research is defining the variety of impacts and the functional capabilities of each eco design tool, through the evaluation of various eco design methods through the application of diverse eco evaluation methods.

Organisation:

For this analysis stage, the author surveyed several organisations, which could undertake LCA in Korea. Suwon University was practically and academically capable, therefore the author officially contacted them and the university undertook a multidisciplinary project, which involved the design faculty.

Outcome:

Through LCA, it provided various current and potential environmental impacts and also presented LCA results from eight different design models, based on the current mobile phone's LCA. On applying the Eco compass method, it used the radar type of tool, which compared advantages and disadvantages.

In order to make the inventory list for the usage level, the author undertook the mobile phone user behaviour analysis to understand the energy consumption levels and of user behaviours.

- Finding the appropriateness of eco design tools in different area

FGI / Discussion

The purpose of this research was to show various evaluation results for environmental and business perspectives, finding possibilities and appropriateness for the use in particular industries. Hence, the research required a wide range of considerations and opinions.

Organisation:

In undertaking FGI, CEOs, marketers, engineers, designers and mobile phone users, (heavy and light users) joined this research with a Korean design Company A t an arranged time and place. A seminar was given to enable teaching re eco design

tools, which were used in this research and also explained LCA results production and analysis.

Outcome:

There were discussions with clear opinions from differing areas and also current circumstances. FGI provided three different major issues: limitations, essential factors and major conditions of eco design from different perspectives.

When using FGI, the discussion revealed major concerns; i) the reliability, ii) productivity and iii) marketability. According to their opinions, firstly, re reliability, the [partners though they needed more research knowledge in order to invest and appeal to the markets. CEOs in particular wanted to invest in eco products but there were still invisible barriers due to eco product requirements and thought they needed more time.

Secondly, the productivity required more knowledge re eco technologies and more research based experts based in the companies with an expansion and development of infrastructure and networks. Finally, to facilitate this marketability, with marketing in mind eco product or eco approaches may add more value with marketing approaches becoming stronger. Some CEOs thoughts were that eco issues have been the most powerful PR factors in global terms already and if company could not deal with it effectively then may not be survive in the near future and also the eco product, is applied eco design tools such as this research has not been existed yet so it will be the new emerging market after that.

Summary

This chapter sought to develop a means of evaluating the appropriateness of eco design tools within Korean organisation. Having a initially failed to ascertain the up take of such tools within design teams, if focus shifted to a comparative evaluation of such tools in a hypothetical scenario. These necessities the combination of range of different means of measuring eco impacts.

Summary of chapter 5

- The structure of this research has 4 levels of framework and each level is related to different categories of the eco-compass
- To implement this research, it has two different contexts (in & outside of company) of research field
- To generate the appropriate design practice through student design projects, the author established the matrix for evaluating and assessing with industrial designers (professor Chung)
- The Matrix requires combining environmental and traditional industrial design aspects such as productivity, emotional satisfaction and marketability
- To undertake the student design works, the researcher built the guideline that how to make understanding eco design methods, how & where to do student and how to evaluate the work result.

Chapter 6. Implementation of Student design works for providing background data for LCA research adoption

Precis of chapter 6

- Determine strength and difficulties of eco design methods via students design works
- Determine and select 8 eco design methods by evaluation matrix and Eco design strategy wheel, which were reflecting traditional industrial values
- Explore and find the better guideline for group design works for learning and undertaking eco design by adopting eco design methods
- Addressing the difficulties that how and what difficulties came from different target group and design object to eco design methods

This chapter presents the results from various design exercise and evaluations for the research.

In chapter 5 (research methodology), the research focused on eco design methods, cross comparing environmental effectiveness against the appropriateness for company eco design therefore, this research requires verification for hypothetical design exercises and qualitative evaluations.

To generate this essential data, the researcher implemented interviews with the purpose of interviewing mobile phone users, and will be focused on i) assessing mobile phone user behaviour, ii) ranking the influencing factors in purchasing, and iii) finding usage patterns for mobile phones to understand energy consumption. The purpose of the expert interviews will find i) ranking and importance factors in LCA and Eco Compass, ii) potential eco design opportunities within different sectors of the company, and iii) to establish a priority for eco design issue strategically. From undertaking service provider interviews, the research will show i) what factors that will most impact decision making for purchasing and ii) which factors will be significant for the mobile phone service.

6.1 Framework for undertaking research

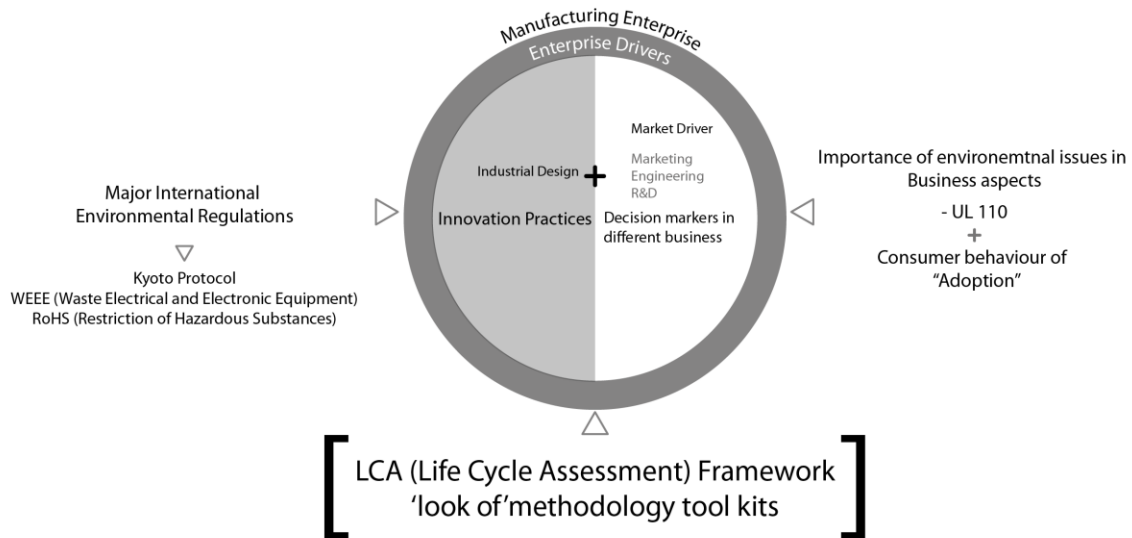


Figure 6.1 Structure of research framework

This research study centred on industrial design perspectives, which also reflected other business perspectives. Referring to chapters 3 and 5, which explained the general features of each eco design method and how to achieve this research through academic structure, they also mentioned how to implement eco product development and how to recognise eco issues in manufacturing. Namely, definition of industrial perspective means that traditionally product designers and transportation designers shows the obvious features to distinguished with engineers. Referring to Phil Baker (2008) demonstrated the differentiations between designers and engineers that are designer shows the basis by emotionally and also designer decodes this emotional data to visual transforming. Therefore this research defined the industrial designer's perspective means that i) emotional understanding, ii) qualitative analysis and iii) centred on principle of industrial design, which has to consider the marketability and productivity both.

According to this previous research, the manufactures have considered 'eco product development' which requires economic risks through large scale investment against producing uncertain economic results, therefore as previously mentioned, undertaking eco-friendly product development projects has been defined as only social contribution or traditionally as non-economically based projects. Furthermore, this kind of project has been distanced from the industrial design area by referring to

many existing products which only focused on new high technologies and moreover other areas such as marketing, R&D and engineering have more opportunities to decide whether to proceed with the eco product development or not.

Such as these aspects occurred is demonstrated in Jakub Kronenberg's book (2007). This author asserted that to achieve the eco design, it requires several significant issues such as the manufactures investments and consumers' understanding. Because historically to achieve effective and recognizable eco design require innovative ecological technologies rather than using or applying current existed technologies and that means mostly 'Eco or Green' has showed the higher contribution to environmental and social benefits than general product innovation.

This diagram demonstrates the research structure for balancing the two different perspectives between environmental requirement and business aspect. This structure applied an LCA framework, which focused on environmental impact for material toxicities and energy consumption during the product lifetime (see chapter 7 and appendix 6), which can provide a new toolkit to produce quantitative evidence which validates and necessitates the implementation of environmental product development from environmental, social and business perspectives. In conclusion, these toolkits, which will build through this research, will provide an effective process to adapt environmental issues into business requirements which may be from market trends and social considerations, bringing new paradigms of product development reflecting not only environmental aspects but will bring economic benefit e.g. energy saving and material reductions.

6.1.1 Building the students experiments

To complete the application of eco design methods and evaluations, the researcher undertook collaboration work with Korean universities (Kookmain and Kyung-Hee Universities; more information in chapter 5) to carry out the student design exercises. To implement effective design exercises the author selected eight eco design methods from a strategic guideline (section 3.2.1.1.1) and presented each eco design method to each team separately before starting the design.

Consequently, in selecting standards (section 3.2.1.1.1 and 3.2.1.1.2) i) the tool has to be effective to adapt to the LCA results, ii) it needs to be translated within the entire product lifespan, iii) the applied results from this tool have to be easily decoded by designers through analysis and visualisation (avoid matrix and numerical value type), iv) each LCA result can be compared through this tool and v) the tool has to compare the comparing results between current products and applied eco design tool data (this may also suggest gaps between the possibility of realisation from manufacturers and the application for maximising design issues).

Moreover, as mentioned in chapter 5, professor, PhD and MA students participated to evaluate the student design results. As the BA, MA and PhD students joined to this research, MA students covered and advised to BA students who have not had research projects and programm and therefore these MA students have taken to team leaders and research assistance. In roles of PhD students were controlled the students and observing the entire issues during the students work for finding and exploring expected and unexpected issues that could be occurred and recording the research reports.

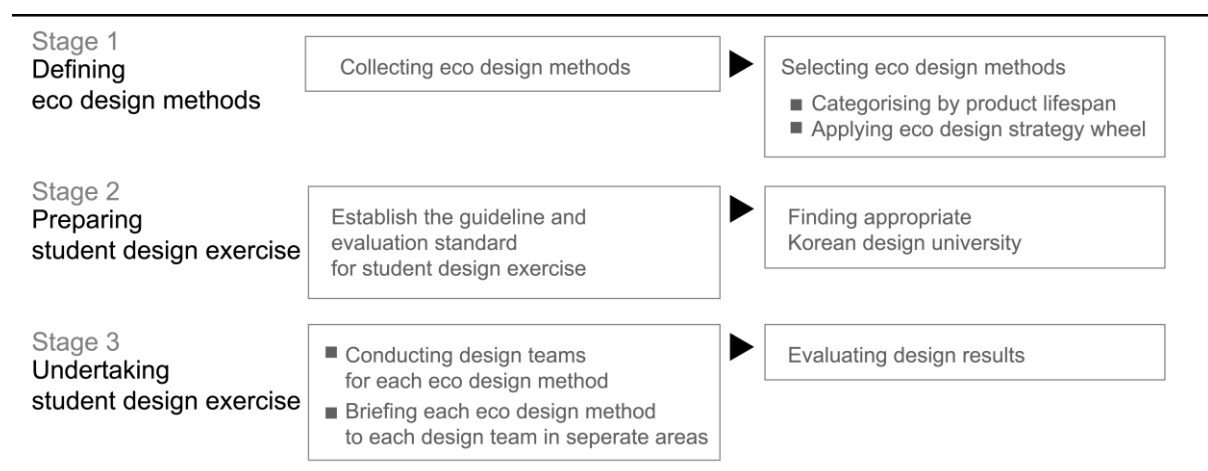


Figure 6.2 Process for finding research results

Figure 6.2 shows the process for student design exercises. In the first stage, the researcher collected information regarding eco design methods through literature review and used these to verify the quality of the data and categorise the eco design

methods for applying design exercise – the approaches and guideline for selecting standards presented in section 3.2.1.1.2-.

The key aspects in selecting the eco design methods should expose the features of each method through design which means the methods have to be focused on the design approach rather than using innovative energy technologies, new eco-friendly materials or innovatively improved services.

The selected design methods were presented via documentation briefly in separate rooms, whilst PhD and MA students (who did evaluations in design aspects) attended the presentation to understand the definitions and features of each eco design method.

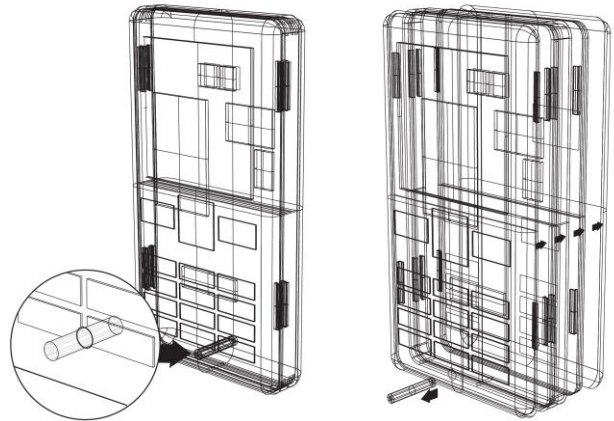
During the presentation of eco design methods to each team, the author found that there were different times required for feedback and understanding of the eco design methods. For instance, Anti-fashion took the longest time (one hour and thirty minutes) to understand and students also expressed difficulties during the design phase.

In contrast, Upgradability was the most understandable and acceptable method to the students. The differences were that Anti-fashion needed to give emotional satisfaction to customers which also needs large scale marketing to extend the product lifespan. Designers have to find the average emotional standards and needs to connect this to marketing functions. However, Upgradability had a similar approach to traditional industrial design methods such as undertaking design by focusing on strong physical type of concepts.

6.1.2 Undertaking eco design tools on the mobile phone design

● Applying the DFD Method to mobile phones

Dimension	107.5(L) X 61.2(W) X11.9(H)
Weight	96.3(g)



Picture 6.1 Example of applying DFD design method to the mobile phone

DfD (Design for Disassembly) has started from how to reduce or simplified manufacturing process in engineering and planning aspects hence, this method is based on rational and quantitative data. As this method transformed the aims to reduce the emission environmental materials and finding more efficiency of process both, this method required more multidisciplinary approach.

This picture shows the DFD design method, which focuses on production and disposal. A simple concept of DFD is that it reduced the number of joints through fewer and stronger joints. With the above concept, each part is joined through sliding slots and the bottom by only one joint. In fact a mobile phone normally has six or seven joints and the problem with this is hiding them from the surface and also on different models and manufacturers, the location of mobile phone joints are different.

This concept mobile phone may solve recent disposal problems such as difficult disassembly and also DFD can reduce production processes. This can also increase repair and upgrade percentages through easier disassembly. However negative features of this concept are i) this concept is physically weaker than normal products ii) consumers can disassemble this easily. According to Samsung Mobile phone designer (March, 2010), Samsung has got a manual for developing mobile phone processes called “product reliability”. The major contents of this are reducing any

harmful situation through the design so they recommended DFD needs a more sophisticated attachment instead of many joints and that the attachment has to be protected from entire outside.

In summary, DFD only focuses on production and disposal levels. Therefore this method has the most problems, which occurred in usage such as physical weakness and breakage through consumer carelessness.

● Applying the Recycling Method to mobile phones



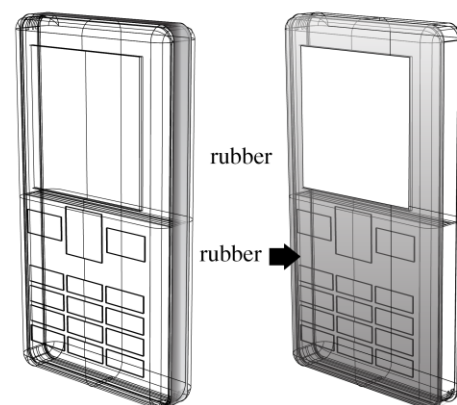
Picture 6.2 Example of applying Recycling design method to the mobile phone

Recycling is the most passive within the eco methods. To achieve recycling, there are several conditions. Firstly recycling requires collecting system. Most advanced and developing countries have undertaken a collection system. The recycling method depends strongly on the consumer behaviour. Secondly recycling is not on the product lifespan. The product lifespan consists of production, usage and disposal however recycling is located between production and dispose and it means recycling is concerned with both processes. Thirdly, recycling requires facilities to extract or dissolve. Recycling re-uses material to produce other materials. For example, recycling paper needs 10% of pure pulp and 50% good quality paper and 40% normal or below quality paper.

“Recycling” has often been confused with “Reuse” however meaning of recycling and reuse are completely different concepts. Reuse uses waste product to remake other products but recycling is all about material issues. Sometimes recycling only uses one or two components or materials or only focus on characteristics of materials.

● Applying the Durability Method to mobile phones

Dimension	107.5(L) X 61.2(W) X 11.9(H)
Weight	98.2(g)



Picture 6.3 Example of applying Durability design method to the mobile phone

New material development may be the key issue to open up the revolutionary environmentally friendly product era. Developing new materials and changing design concepts to more eco-friendly products can lead to the next step in achieving eco-societies.

The concept of durability is to extend product lifespan however it demands new eco materials to extend this or find ways to have less impact on the environment such as changing surfaces, structure of material and systemically reinforcing PCB and housings.

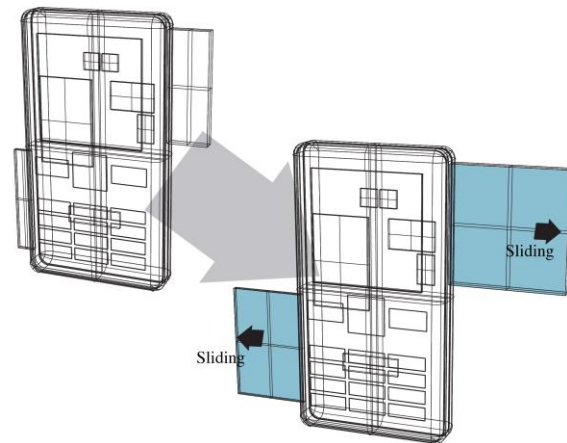
This design considered the surface of the housing and the outside composition. The concept changed the housing material, used rubber or any other protectable material instead of PVC (this material is breakable and a banned eco material due to product disposal problems).

To achieve durability, the product design protects the structure for mobile phone equipment especially weaknesses such as digital camera and MP3 player from the physical impact on the outside. However the eco design model did not receive a positive account in LCA because LCA, which the author undertook only focuses on production levels in this experiment.

● Applying the Upgradable Method to mobile phones

Dimension	107.5(L) X 61.2(W) X11.9(H)
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Weight	101.5(g)
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Picture 6.4 Example of applying Upgradable design method to the mobile phone

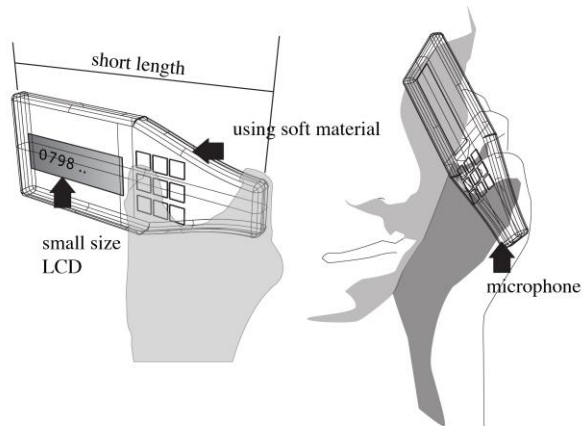
Upgradable design method can show the most commercial factors and fulfill user's functional and aesthetical demands at the same time therefore through this method consumers will use this model for longer periods and major mobile phone markets will also change from selling new mobile phones to selling contents and upgrade components. However this needs PCB engineering innovation, which demands high investment costs and time. This also demands new layout design for realising because the major components are the camera, speaker and LCD and are mostly located on top of mobile phones.

This design of a PCB board is divided into two and it can slide to the outside of the mobile phone housing for easier upgrade or repair. This method can continuously stimulate consumer concerns re functional satisfaction. This method also supports tuning the mobile phone for the consumer preference.

This idea is unique and interacts with users and provides solutions for eco design approaches to customise and innovate to attract more consumers.

- **Applying Material reduction Methods to mobile phones**

Dimension	124.4(L) X 55.8(W) X 11.9(H)
Weight	105.4(g)



Picture 6.5 Example of applying Upgradable design method to the mobile phone

The definition for this method is “limiting amounts of resource used and waste production”. This also reduces waste space through planning the device structure.

If the product reduced physical size then can we call it an eco-product?

Recent global electronic product markets have grown, especially the tablet PC market, with products such as the Samsung Galaxy Tab and the Apple I-Pad and the smart phone market is the hottest global market. These products all use reduced waste, internal space efficiency and are lightweight. However we cannot say that these are not eco-friendly products at all.

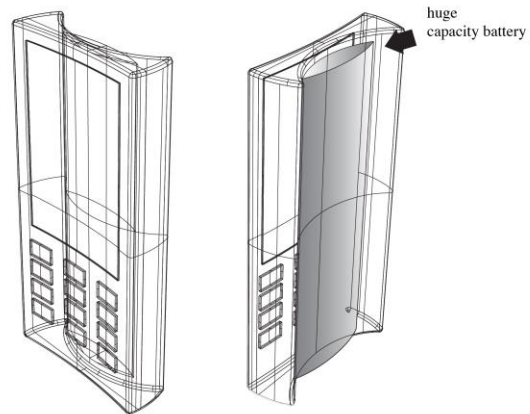
Reducing physical size does not necessarily depict eco-friendly or non-eco-friendly products. For instance, to reduce the waste space, special material needs to be used, but if higher environmental impact ensues then this product is not an eco-friendly product.

With design, the reduction of the size of the LCD panel and followed by number key size reductions is seen as eco-friendly. However it then makes it more difficult to hold, it has been designed longer, like a bar type product. The handgrip is made of soft material such as rubber or hard sponge and these materials also use lightweight materials.

● Applying the Energy saving Method to mobile phones

Dimension	107.5(L) X 61.2(W) X 11.9(H)
-----------	------------------------------

Weight	88.5(g)
--------	---------



Picture 6.6 Example of applying Energy Saving design methods to mobile phones

The aim of the Energy saving method is to reduce waste electrical energy through the development of technologies and designs. In fact, engineering approaches such as improved electrical efficiency or developing alternative energy sources can be a more powerful solution rather than the design approach. On the surface, design perspectives can decide the approximate size of products, battery attachment or proportions between batteries, LCDs and entire products.

However Energy saving design methods not only decides sizes of component?

Energy saving design methods have been concerned with consumers and developers because designers have tried to develop eco contents particularly within building construction.



Picture 6.7 EDF adapter for energy saving in living place

This picture shows an example of an energy saving method and this product is designed to control sockets. This energy saving method can be used in mobile phone design.

In a test, designers designed larger batteries to reduce the number of charges because during changing, between 80 and 90 % of electricity is wasted. They also designed a function to reduce electrical waste. This needs interface design and content design such as feedback and shortcut functions to reduce waste further.

In summary, the best way to save energy is through innovation technologies such as new battery types or changing mobile phone PUI, GUI interfaces, however designs can change mobile phones that result in sophisticated problems such as consumer behaviour and cultural identities through design research so Energy saving methods have to combine design issues with engineering issues to maximise the effect.

- **Applying the Anti-fashion Method to mobile phones**

Dimension	107.5(L) X 61.2(W) X 11.9(H)
Weight	96.3(g)



Picture 6.8 Example of applying Anti-fashion design method to the mobile phone

Anti-Fashion is only one approach to eco design through aesthetic factors. The definition of this method is to find the satisfaction factor and common product standards for target users and apply average standards from that research.

The most important condition of this method is this tool has to use very authentic shapes.



Picture 6.9 Oral B Cross action: authentic toothbrush model and Nokia 1100: World best seller

The Oral B toothbrush is one good example. Lunar design in San Francisco designed the original Oral B toothbrush ten years ago but this product is still selling in the market and the toothbrush has explored new products in this time.

In the mobile phone market, the Nokia 1100 closely achieves this through design by understanding and decoding requirements for all ages effectively. This low-end candy bar mobile phone was one of the longest sellers and this was sold to two hundred million people in the global market.

However successful research, finding common standards and satisfaction factors with applied Anti-fashion methods then can these products be called eco products?

Applying the Anti-fashion design method also needs to fulfil eco guideline which are i) evaluating extending product emotional lifespan, ii) estimating impact to the environment for production and disposal and iii) calculating economic validity. This method can be applied with other tools such as DFD and Durability, which focus on functional abilities.

- **Applying the Reduced function Method to mobile phones**

Dimension	100.5(L) X 61.2(W) X 11.9(H)
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Weight	86.3(g)
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Picture 6.10 Example of applying reduced function design method to the mobile phone

The feature if this design method only concentrates on the original product functions.

In mobile phone functions, this method focuses on communication ability within four different areas which are: i) communication, ii) mobile Internet access, iii) digital camera and iv) MP3 player.

Picture 6.10 shows an example of LCA testing where design only focuses on communication functions so designers design larger key panels and icons.

The weakness of this method is that it falls behind in the smart phone market so this method needs to improve specialised quality of communication. It also needs to develop eco materials for products and impact communication technology instead of reducing functionality.

The supplement for this method is that i) this product has to connect with other devices such as computers to use alternative interfaces and ii) also connect with other mobile phones to use Cloud Computer Technology.

6.1.3 Summary

Each eco design method has different issues / problems (section 6.1.1) hence it requires time to understand these methods depending on the difficulty of the issue / problem.

Each space means time distance (5 minutes) and shortest time spent was Upgradability method that only took 47 minutes. Average time spending was 65.8 minutes and this result showed the 5~6 minutes gap with the researcher's hypothetical plan (60 minutes) hence these students had not had eco design experience.

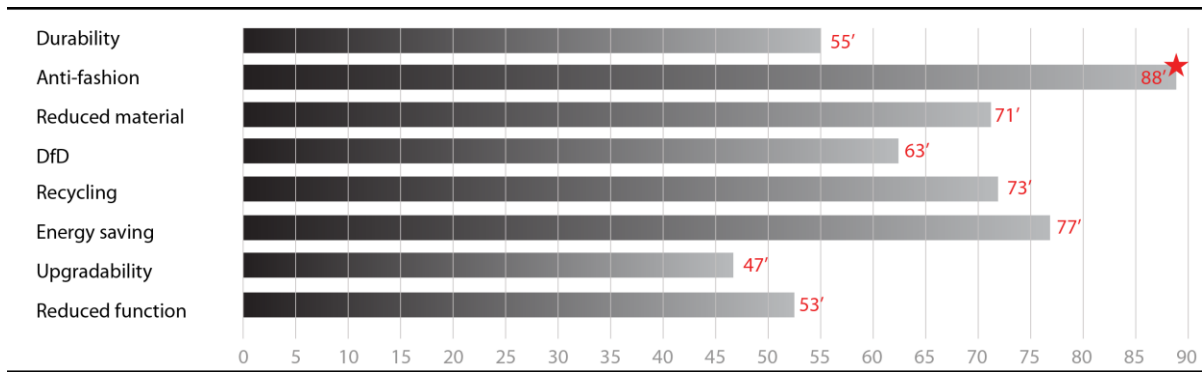


Figure 6.3 Time for understanding eco design methods

The presented eco design methods had similar structures or approaches to traditional product processes which spent shorter times understanding and implementing. In contrast, eco design methods are based on the technology, market knowledge base and emotional approach requiring more time for methods such as Anti-fashion and Energy saving. These issues occurred from design students in Kookmin University and also occurred in Kyung hee University students as well.

According to Figure 6.3, using eco design methods in the design area needs to provide a basic manual, particularly for dissimilar approaches and structures with product mechanisms for effective design results. It also requires other experts such as engineers and marketers to provide extended design thinking knowledge.

This research will show the appropriate eco design methods to provide a balance between environmental and economic benefit and also appropriate methods for designer's use. To find out whether eco design methods fulfil these conditions, the research applied 8 eco design methods to the design for generating design agendas and implementing qualitative ecological evaluations.

Through this exercise, eco design methods require environmental and economic values but also need similar approaches or structures to traditional product design methods which means using and learning eco design methods where designers have to consider difficulties and learning periods.

Consequently, eco design methods have a different purpose of use but also designers need to consider the project condition and decide upon appropriate eco design methods for capability, time and investment.

Eco design methods	Upgradability	DfD	Durability	Reduced Function	Anti-fashion	Energy Saving	Recycling	Reduced material
Ranking	1	4	3	2	8	7	6	5

Table 6.1 Difficulties of understating each eco design method

Table 6.1 was based on results of figure 6.3, which showed different rates of understanding difficulties. These rankings were simply showed understanding rates means were not included actual design works because students design work spent much longer time and had infrequent questions therefore the researcher could not calculate and analysis quantitatively.

This ranking shows difficulties reflected in spending time learning and giving feedback. Although there were slightly different degrees depending on the make-up of the eco design methods, the biggest influence to affect the results might be how related these are to traditional industrial design approaches and what approaches are used to generate ideas.

During the design exercise, the author found the three important factors which can impact the level of learning eco design methods and create the value for eco design.

- Capability of designers: having various design experiences and implementing a wide range of design activities can influence the adoption of eco design methods. During the student exercise the author spent 70 minutes on average but in contrast, professional designers may spend a shorter time to understand but may find it more difficult to apply these methods effectively.
- Understanding design objects: the objects which designers have designed for a long period can be more understandable. Therefore comparing these to unfamiliar objects, this may be more suitable to apply eco design methods and could find easier ways for using eco design methods.

- Communicating ability with other functional areas: during this research, the researcher found that using eco design methods effectively requires ecological evaluation and understanding of these methods. To achieve these requirements, designers have to understand other area perspectives therefore reducing rates of interpretation error and to increase higher efficiency of eco design methods.

In summary, this exercise presents i) different difficulties of eco design methods through educational circumstances, ii) illustrated what factors have negative influences to designers during the learning of eco design methods and iii) what influences traditional industrial design approaches can have and affect the learning of eco design methods.

Summary of chapter 6

- Designers' understanding about eco design methods varied in terms of types of approaches and requirements e.g. upgradability and durability – these were easier to understand as compared to for example anti-fashion. Anti fashion is based on the marketing aspects and recycling method requires social awareness and special systems
- Averagely to understand eco design methods, 65.8 minutes spent for BA students, who have not many of environmental design experience
- In case of Anti fashion, this could not explain by single area means this requires multidisciplinary approach such as design, marketing and public relationship
- In case of Anti fashion, which needs to consider entire aspects spending more time to understand hence as difficulties higher
- Pace of understanding varies depending on the time available to learn the eco design method – variation from 47 to 88 minutes
- To find appropriate eco design results, the author applied the guidelines for group design works and professional practice seminars

Chapter 7. Structure of LCA research

Precis of chapter 7

- Determine how to implement environmental quantitative evaluations for finding the effectiveness of each eco design method in particular industry
- Determine how to sourcing of the LCA experts for the research
- Building the inventory lists for implementing LCA
- Finding better operating programmes - (Simapro 6 / Gabi 4)

This chapter shows that how to establish the structure for undertaking LCA and what will be the results in each eco design method. Particularly, the values of this chapter are i) showing the different environmental values of each eco design method in the different phase of product lifespan and ii) deducting and proofing the different types of strength of each eco design method. The author has undertaken to build the inventory list and found the appropriate LCA program for making the effective LCA results.

- Results of the current mobile phone and 8 different types of ECO designed mobile phone through LCA

	Number of Methods	Subject	Period	Place
Context	Eight eco design methods	Designed concept analysis by LCA	Jul 2009	Suwon University

Table 7.1 Results from Suwon University

These results came from Suwon University LCA centre and the Ministry of Industry in Korea. The mobile phone used for the experiment was a Sony Ericsson bar type PDA (2G) phone.

LCA requires pre-analysis data such as material and energy inventory lists, manufacturing processes and measuring amounts of CO₂ and waste emission (see appendix 4. Inventory list).

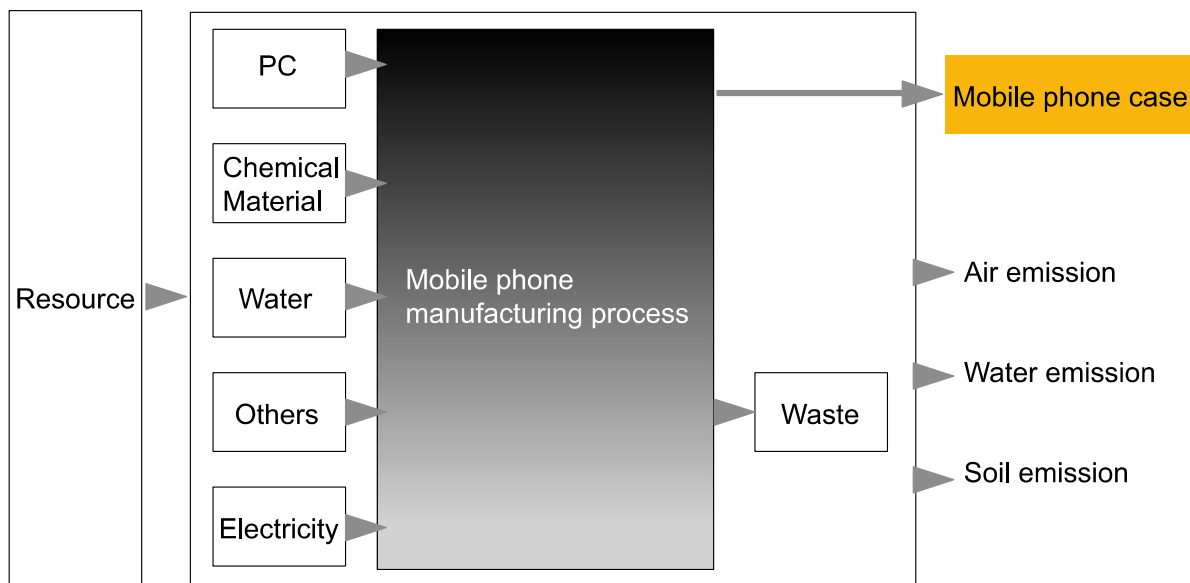


Figure 7.1 Product system of mobile phone case

7.1 Preparing for the data collection

The system limit for this test is “cradle to gate” process, is from the production material level to production of the mobile phone case level. Most data collected has been provided from the company directly. Figure 7.3 illustrates the structure for influencing the mobile phone housing, showing the fundamental input material; the three major emissions are air, water and soil at production level. The LCA in this research was limited due to i) the manufacturing and disposal process of mobile phone was highly confidential for the company and ii) the purpose of this research was to find effective eco design methods from different perspectives therefore making the conditions equivalent rather than applying complex processes with more significant requirements. This diagram is based on the Cradle to gate concept; most waste mobile phones have not been recycled (chapter 2). Cradle to gate is an assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (i.e., before it is transported to the consumer). The user phase and disposal phase of the product are omitted in this case.

7.1.1 Data collection

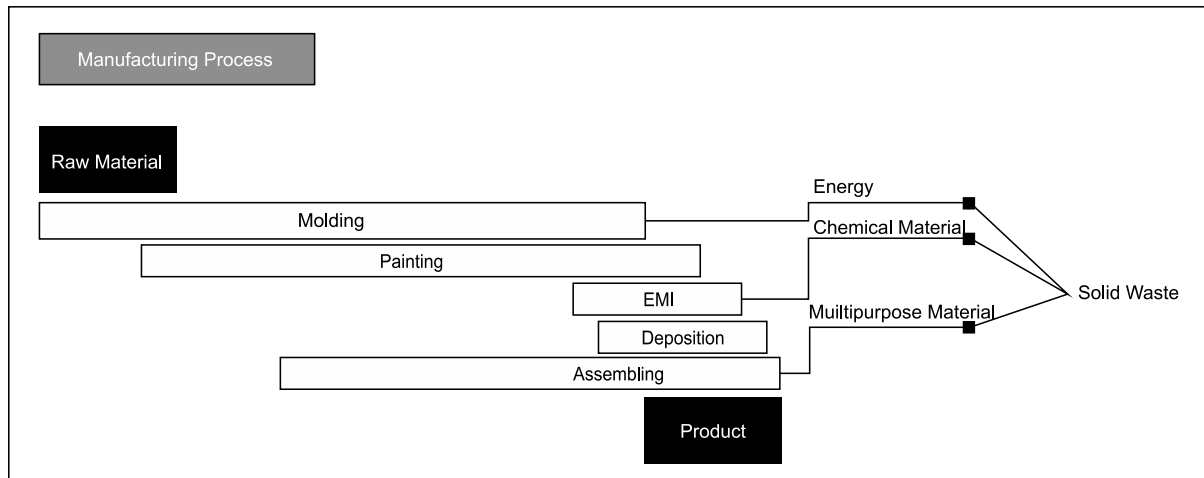


Figure 7.2 System limit and a mobile phone case manufacturing process

Data collection was implemented by the above production process (figure 7.2) in this research. LCA for this research omitted resource collection and shipping process and focused more on the input and emission materials.

The major product manufacturing process is moulding, painting, EMI, deposition and assembly. The research used various designs for producing forms (shapes) at moulding level and scrap occurred during this process. Most scrap has been recycled and after the paint process, it processes EMI, which is for protecting from electromagnetic waves and the deposition process. **Almost of IT and digital mobile communication equipment such as computer controller, industrial communicator and micro phone are included mobile phone have the electromagnetic interference (EMI). The EMI influences to strength of noise and quality of communication. Therefore the aim of EMI plating is how to reduce these variety interferences of product quality and how to protect the health from the electromagnetic wave.**

7.1.2 Quantified data of input and emission collection

For evaluating environmental effectiveness, the author collected extensive data for all manufacturing processes. Data collection was undertaken through interviews, literature review and research. The limit of this test was finding and using the most recent complete mobile phone data. Therefore we used 2004's model.

A. Resource

An OEM Company provided the test data for the major components in the assembly process and this data centred on July, 2004.

B. Energy

The author calculated amounts of electricity in all manufacturing process in July, 2004.

C. Chemical material

Resin in the moulding process, paint and thinner in the paint process and EMI material were all chemical materials. This data was calculated in July, 2004.

D. Utilities

This process also demands water with chemical material.

E. Industrial Waste

Industrial waste emitted from the moulding, EMI and deposition process was calculated. Most waste was scrap and EMI material and waste non-woven fabric.

F. Water emission

Most industrial wasted water has been harshly treated in the factory.

	Input			Emission		
	Resource / components	Chemical material	Energy	Air emission	Water emission	Industrial Waste
Manufacturing process	●	●	●	-	●	○

Figure 7.3 List of data collection ●Actual measurement ○Literature review and Calculating ▲ Estimation

7.1.3 Data analysis preparation

A. Calculating data

A.1 Moulding Process

One product has two components, is front and rear cover so this inventory list was based on the only two parts.

a. Resource

10 different materials were used in the moulding process. However it was impossible to consider all different material to calculate therefore we calculated the relationship between total materials used and amount of scrap. After that the researcher added the weight of the products, amount of resource necessary and amount of scrap emission to the analysis.

b. Energy

In gaining more exact data, firstly the researcher surveyed the amount of electricity used in the moulding process and considered the total amount of electricity used.

c. Chemical material and industrial water

Four major chemical materials used are cleaners, separating materials, rust inhibitors and lubricating oil used during the moulding process. The researcher only considered total amount of chemical materials used in July, 2004.

d. Industrial waste

During manufacturing, defective products and scrap emitted were recycled by the recycling expert.

A.2 Painting process

Mobile phones need two parts painting (front and rear covers) so the researcher only considered these parts.

a. Chemical material

The largest pollutant chemical material was thinner and the paint for coating and finishing. The researcher also considered the proportions of NaOH and cohesive agents used.

b. Energy

The researcher found the relationships between electricity, LNG, water use and amounts of production in July, 2004.

c. Industrial water emission

Industrial wastewater was emitted during the painting however 100% of this was purified in-house. The researcher calculated actual amounts of water emission per product produced in July, 2004.

d. Industrial waste

Painting produced defective products and wastewater. Compared to other products, a mobile phone produces higher defect rates.

A.3 EMI, deposition process

Inside and outside components need EMI treatment. In this test, the researcher only considered EMI treatment and the deposit process.

a. Chemical material

The research surveyed the relationship with amounts of paints used and products produced in July 2004 and calculated the total amount of materials and paints used.

b. Energy and industrial water

The researcher reviewed the relationship between electricity, LNG, water use and amount of production in July, 2004.

c. Industrial waste

Non-woven fabric waste and waste paint emitted during this process were used. 100% of the waste paints were collected by contracting out and only silver was melted in paint recycling. Therefore we considered the percentage of silver used and recycling percentages.

A.4 Assembly process

This process can be divided into two levels, one for collection from other companies and another for assembling all together including the PCB and the LCD.

a. Components

A mobile phone consists of a front cover, rear cover and internal parts. The researcher developed the inventory list based on 3 elements. The inventory list has 3 key factors; material, weight and density.

b. Energy

The company only manages the amount of electricity use in the moulding process therefore the research considered total amounts of electricity used.

c. Industrial waste

Most defective products are recycled through outsourcing. The research applied product weight to percentage of production emissions.

B. Verification

The research centres used were Su won university and Sam-kwang Lt.D, which are OEM mobile phone manufacturers for the credibility of data collected.

Below is a list that was verified:

- Mass Transfer
- Reference and year of data collection
- Unit measurement
- Checking parameter emissions

B.1 Mass Transfer

The definition of “Mass Transfer” theory is the quantity of input and output material which equals by the formula for mass conservation however in this case, non-emitted material such as electricity was excluded in the verification list.

An LCA report from the Korean Ministry of Industry, where the product is correlated between materials included in the product and components therefore the research tried to apply it to the LCA program.

$$\text{Weight of input resource} \geq \text{Weight of final product}$$

The reason for this is that when the product is produced, scrap and defective products are also produced, which means that excluding some input material or different amounts of input material within the inventory list.

Therefore we used this correlation for verification of the inventory list before undertaking LCA analysis.

B.2 Reference and year of data collection

Data should be the latest version to correspond to global eco restrictions therefore we checked and supplemented collected updated data

B.3 Unit measure and checking parameter omissions

Many companies have their own managing units so we transferred to Kg (mass) and Kwh (electricity).

7.2 LCA analysis for current mobile phone

To find the environmental impacts of each eco design method, the author undertook the LCA to current mobile phone as the control group for comparing analysis. This data will be the standard to compare LCA results of each eco design method.

The author and LCA expert undertook LCA on mobile phone cases through potential environmental effectiveness which are abiotic resource depletion (ARD), global warming (GW), Ozone depletion (OD), acidification (ACID), eutrophication (EU), photochemical oxidant creation (POC), human toxicity (HT) and eco toxicity (ET) and

we added, specialised, standardised and divided the LCA method from the Korean Ministry of Industry.

For understanding the potential capability of environmental effectiveness for mobile phone cases, we divided the manufacturing process into moulding, painting, EMI, deposition and assembling processes.

7.2.1 LCA result of specialisation of current mobile phones

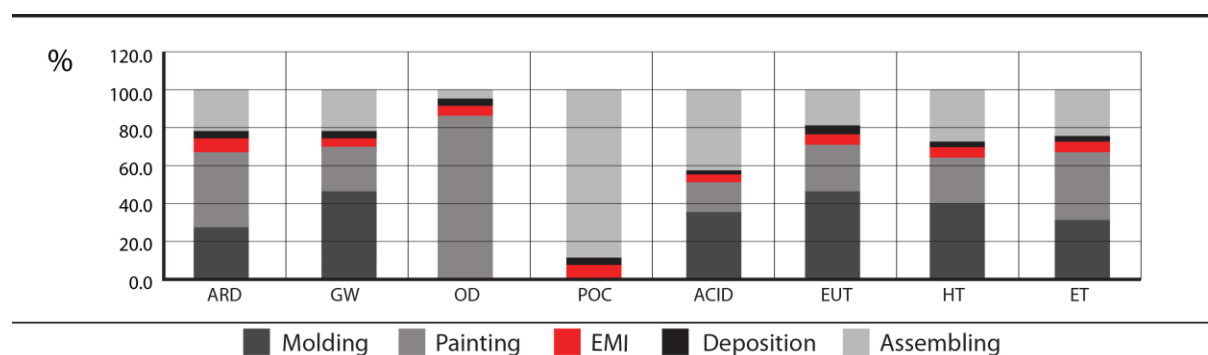


Figure 7.4 Contribution to specialisation by manufacturing process for each environmental effectiveness factor

This figure illustrates total LCA results and shows what manufacturing process gives more environmental impacts of current mobile phone. For instance, referring to this figure the painting process is giving the most environmental impacts and molding process followed in abiotic resource depletion (ARD).

The result shows different percentages of potential eco effectiveness as a feature of the manufacturing process. The moulding process has a high eco influence in ARD, GW, ACID, EU, HT and ET. The painting process also affects all eco effectiveness, except POC and in particular it gives an impact of OD of over 80%. The assembly process, for all input components highly influences POC.

- LCA result of raw material exhaustion

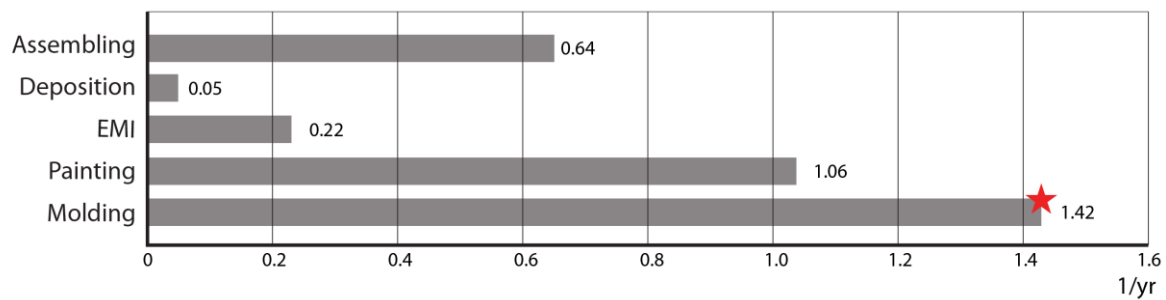


Figure 7.5 LCA result of raw material exhaustion

This figure quantitatively illustrates how exhausted and consumed the natural materials are and for example the molding process consumed the natural material.

Figure 7.5 shows influences to the environment during the manufacturing process. In this graph, the moulding process has the most significant impact (39.3%) and painting and assembly processes followed (29.9% and 23.3%). The major fuels were 41% crude oil, 36.5% natural gas and 21% coal usage.

93% of electricity used was for the moulding process, the eco impact percentage for using paint thinner was 62% in the paint process and 27% eco impact was for defective products in the assembly process. The results show that the paint process has a higher defective product rate over other manufacturing processes. 64% of the eco-impact was from front and rear cover production using electricity and other components took 19.5% and 13% in the assembly process.

- LCA result of the global warming

Figure 7.8 shows the impact on global warming for each manufacturing process. The largest gCO₂ was the moulding process (48.8%) and painting and assembling process followed at (22.6% and 22%). CO₂ emissions were the largest decision factor (97%) in global warming.

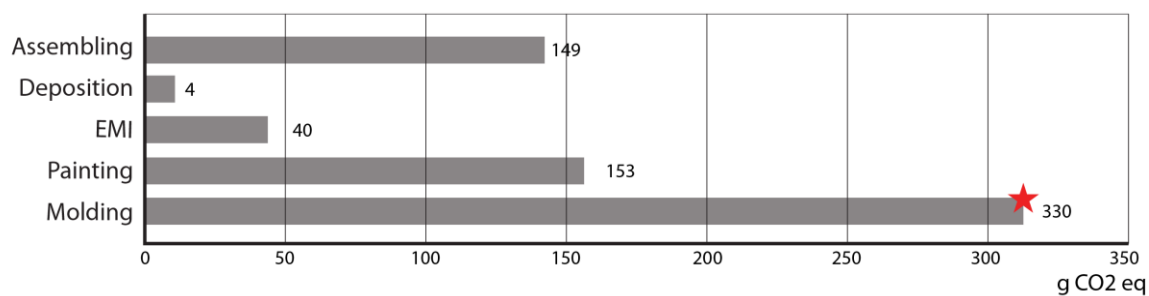


Figure 7.6 LCA result of the global warming

This figure shows that what process impacts to the global warming in LCA and molding process ranked the highest impacts because making the die mold emitted large scale of CO₂ therefore this process gives more environmental impacts comparing to other process.

The largest impact to global warming was electricity use in the moulding process (94%), defective product emissions (50%) and using painter thinner (38%) in the painting process.

- LCA results for Ozone layer destruction

The painting process the highest recorded in Destroy ozone layer factor because the manufacturing mobile phone requires the high quality painting, which has involved toxicities materials and also the painting process needs the gas for spray.

Eco effects for Ozone layer destruction in the paint process, which used paint thinner had an influence of 74% and 25%, use of ethanol took 74% and influenced 7% on the entire potential eco effectiveness. The biggest eco effectiveness for Ozone layer destruction was ²HALON-1301 usage.

² Bromotrifluoromethane : (organic compound) The halogenated hydrocarbon CBrF₃ once used in fire extinguishers

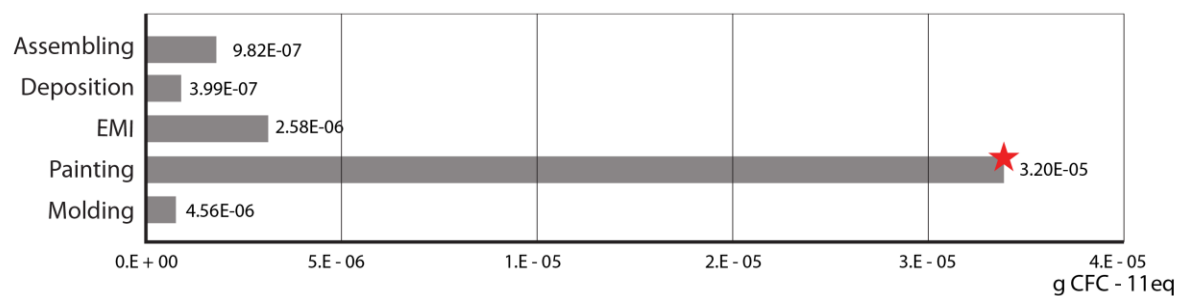


Figure 7.7 LCA result of the ozone layer destroying

- LCA result of the photochemical oxidant creation

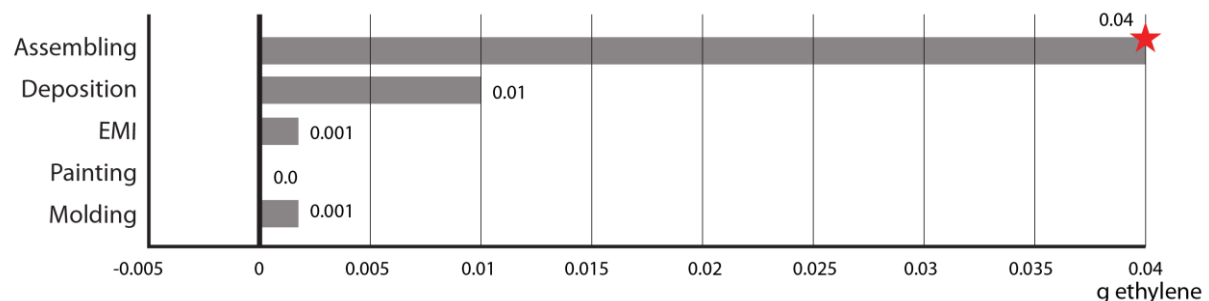


Figure 7.8 LCA result of the photochemical oxidant creation

Photochemical oxidant creation means that how high the rate of photochemical oxidant created and mobile phone manufacturing process does not record significantly high comparing to other electric and electronic product however assembly process recorded 4 times more than deposition process and 40 times more than EMI and molding process.

The eco effect of the photochemical oxidant creation in the assembly process was a major factor (75%) and the deposition process also gave a significant impact (22%). The air pollution emission by the pentane gave the strongest effect (55%) and SO₂ (30%) and the methane gas (11%) followed. 90% of PU, which is contained in the mobile phone component gave effect during the assembling process and 98% of CU, which is involved in the deposited liquid gave an effect in the deposition process.

- LCA result of the acidification

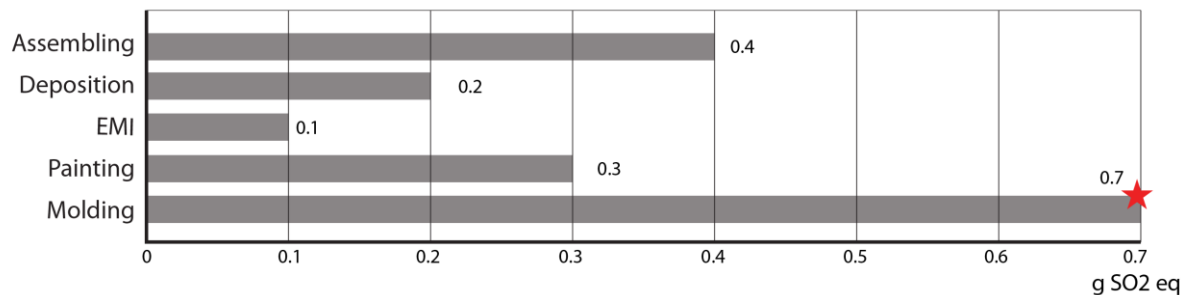


Figure 7.9 LCA result of the acidification

The moulding process influenced 39% of the potential eco effect of the acidification and the assembly and the painting process also gave an effect of 23% and 19%. The significant material factor was 75% of NO_x of air emission and SO₂ emission.

The strongest factors were 91% of electricity usage in the moulding process, 55% for front and rear cover and 22% of electricity usage in the assembly process. The painting process gave an effect of 46% and most of the cause was defective product emissions and paint thinner usage.

- LCA result of the eutrophication

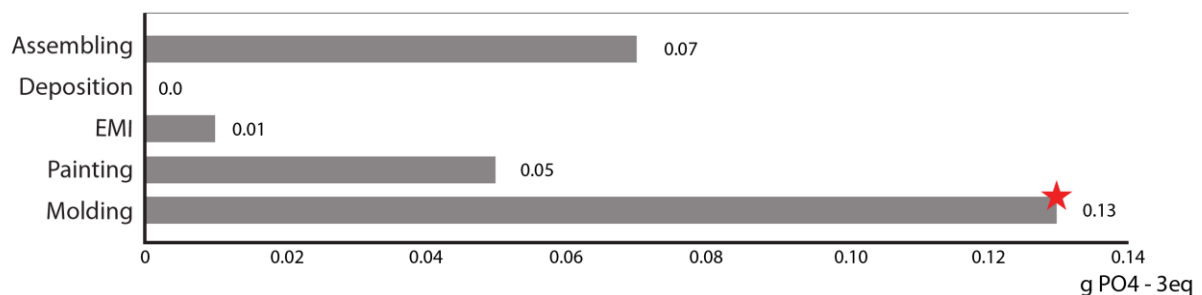


Figure 7.10 LCA result of the eutrophication

The eutrophication of a mobile phone case influenced 48.5% in the moulding process and assembly process (27.5%) and paint process (18.7%) followed the eco effect. 98% of effect caused were NO_x and 4% of water emission of P205.

In the moulding process, electricity gave 89% of the effect and 11% was the usage PC for the scrap emissions. In the assembly process, the biggest impact was the assembly of front and rear covers (62%) and usage of electricity followed (21%).

- Result for human toxicity

The moulding process gave the largest effect to the potential eco effect for the human toxicity factor (41%) and in the analysis this was; SO₂ emission was the major cause (45%). The paint and assembly process followed (27% and 21%)

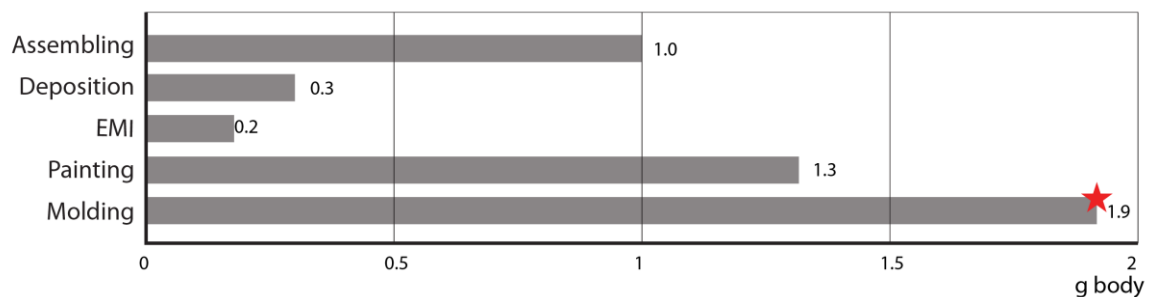


Figure 7.11 LCA result of human toxicity

Using electricity had the largest eco-effect (94%) in the moulding process and defective product emissions were 35% in the paint process and using paint and thinner followed with (32% and 16%). Front and rear cover assembly took 50% and electricity usage took 29% in the assembly process.

7.2.2 Applying the LCA to 8 different types of eco design tools.

The detailed data, LCA applied to eight conceptual design results in appendix 6.

7.3 Summary of LCA results about current mobile phone

Through these LCA results, which the researcher used to evaluate eight eco design methods, illustrates different effects on various environmental impacts. Comparing these methods the author established in the matrix (see table 7.3) shows eight levels of effectiveness. The zero point (datum) (the same value as current mobile phones) is the standard to illustrate the results, the positive points can be distinguished; -

1(slight reduction), -2(Moderate reduction), -3(Severe reduction) and -4(Very severe reduction) and negative points have also three points; +1(Slight increase), +2(Moderate increase) and +3(Severe increase).

	Assembly							
	Anti-fashion	Reduced Function	Reduced Material	DfD	Durability	Upgradable	Recycling	Energy Saving
Raw material exhaustion	0	-1	0	-3	+1	0	0	0
Global warming	0	-2	0	-3	+1	0	-1	0
Ozone layer destroying	0	0	0	-2	+1	0	0	0
Photochemical oxidant creation	0	0	-1	-3	0	0	-1	0
Acidification	0	0	0	-1	0	0	0	-1
Eutrophication	0	0	0	-1	0	0	-1	0
Human toxicity	0	0	0	0	0	0	-1	0
	Deposition							
	Anti-fashion	Reduced Function	Reduced Material	DfD	Durability	Upgradable	Recycling	Energy Saving
Raw material exhaustion	0	0	0	0	0	0	0	0
Global warming	0	0	0	0	0	0	0	0
Ozone layer destroying	0	0	0	0	0	0	0	0
Photochemical oxidant creation	-1	-1	0	0	0	0	0	0
Acidification	0	0	0	0	0	0	0	0
Eutrophication	0	0	0	0	0	0	0	0
Human toxicity	0	0	0	0	0	0	0	0
	EMI							
	Anti-fashion	Reduced Function	Reduced Material	DfD	Durability	Upgradable	Recycling	Energy Saving
Raw material exhaustion	0	-2	0	0	+1	+2	0	-1
Global warming	0	0	0	0	0	0	0	-1
Ozone layer destroying	0	0	0	0	0	0	0	0
Photochemical oxidant creation	0	0	0	0	0	0	0	0
Acidification	0	0	0	0	0	0	0	0
Eutrophication	0	0	0	0	0	0	0	0
Human toxicity	0	-1	0	0	0	0	0	0
	Painting							
	Anti-fashion	Reduced Function	Reduced Material	DfD	Durability	Upgradable	Recycling	Energy Saving
Raw material exhaustion	0	-1	-1	-2	0	0	0	0
Global warming	0	-2	-2	0	0	0	0	-3
Ozone layer destroying	0	-1	-2	0	0	0	0	0
Photochemical oxidant creation	0	0	0	0	0	0	0	0
Acidification	0	0	0	0	0	0	0	0
Eutrophication	0	0	0	0	0	0	0	0
Human toxicity	0	0	0	0	0	-2	0	+1
	Moulding							
	Anti-fashion	Reduced Function	Reduced Material	DfD	Durability	Upgradable	Recycling	Energy Saving
Raw material exhaustion	0	-1	-1	-2	+1	0	0	0
Global warming	0	-1	-4	-3	0	0	0	0
Ozone layer destroying	0	0	0	0	0	0	0	0
Photochemical oxidant creation	0	0	0	0	0	0	0	0
Acidification	0	0	0	-2	0	0	-2	0
Eutrophication	0	0	0	-1	0	0	-2	0
Human toxicity	0	0	0	-2	+1	0	-2	0

Table 7.2 Eco scores in different phases of the production process

This matrix presents the assembly and moulding process, which have the biggest effects and the painting process followed. Using the DfD method in the assembly process innovatively reduced environmental impacts particularly when working on the global warming and photochemical oxidant creation. However, the durability method estimated that it can produce more environmental impacts rather than current mobile phone with raw material exhaustion and global warming. In the deposition process, eco design methods had a limited effect on photochemical oxidant creation because the deposition in the mobile phone production may implement only small component parts compared to other products. Reduced function and reduced material methods mostly affected the painting process. The reasons for these results may be influenced by materials saving and waste reductions factors such as decoration and through this method can also achieve the simplification of production processes. This also showed that the reduced material method can highly reduce global warming in the moulding process and moreover, the DfD method affected the reduction of environmental impact in most categories.

Through these results, this research will suggest the appropriateness of eco design methods in chapter 9 and will implement cross comparison to investigate the major issues giving positive impacts when applying various importance in chapter 10.

Eco design methods		Upgradability	DfD	Durability	Reduced function	Anti-fashion	Energy Saving	Recycling	Reduced material
Ranking	Assembling	6	1	8	3	6	4	2	5
	Deposition	3	3	3	1	1	3	3	3
	EMI	8	3	7	1	3	2	3	3
	Painting	3	5	5	2	5	3	5	1
	Molding	5	1	8	4	5	5	2	3

Table 7.3 LCA score in different phases of process

Table 7.3 shows the ranking of total impact in different processes based on LCA analysis. Namely, that figure did not evaluate eco design method by method. To find the better design method in environmental aspect the author compared to LCA of each eco design method and ranked the position of advantage. To produce these results the author collected various impacts from different sub categories such as global warming, human toxicity etc. however these results can be only present the

environmental impact and find the appropriate eco design methods, in order to reflect the rate of importance, current international regulations, features of the mobile phone industry, business interest and consumers' issues are required.

In this table, reduced function is the most effective methods followed by DfD. The reasons are that these methods can lead to innovation of the production processes and also influence the increasing rate of recycling and extending product lifespan. However, durability and upgradability only focus on extending product and service lifespan. The biggest gaps between these methods are that effective methods have more content and are able to reduce environmental impact to extend and integrate to other aspects. For example the DfD method which considers the disassembly method to increase rates of recycling also impacts on reducing production processes. Another example is the reduced function method which focuses on omitting the waste functions by establishing functional priority, however it is also related to energy saving and reduced materials.

Therefore these results show that eco methods positioned in higher rankings can extend to other ecological areas and also this can develop ways to achieve its purpose.

Summary of chapter 7

- LCA has 8 different facts and phase of manufacturing process recorded in different each fact such as molding process recorded abiotic resource depletion (ARD), global warming (GW), acidification (ACID), eutrophication (EU) and human toxicity (HT), painting process recorded high in ozone depletion (OD), assembling process recorded high in photochemical oxidant creation (POC)
- Referring to LCA results, the manufacturers have to consider in particular process that molding process recorded in 5 environmental impacts facts
- Hypothetically eco design method which is related to reduce the environmental impact in molding process then this would be increased

effectively for making environmental friendly mobile phone

- The LCA results showed DfD and reduced functions were the most effective methods in regard to the environmental perspective
- The methods, which encompass multi-aspects such as DfD can extend product lifespan and increase recycling rates. This DfD recorded better LCA points
 - These results were only produced from LCA, which were not applied to the metrics of the business perspectives

Chapter 8. Interviews (Interviews I - Finding user behaviour / Interview II – Finding the factors of company requires to eco design)

Precis of chapter 8

- Determine what the pattern of typical mobile phone users is in different phase of mobile phone lifespan
- Determine what and how the mobile phone purchasing is accomplished in Korean mobile phone market
- Determine how to establish the standard for dividing mobile phone user groups by features, behaviour and level of satisfactions
- Finding the elements that can be connected separately to environmental and business aspects from the interviews

This research consists of four different sectors; production, usage, disposal and recycling. For defining eco issues in each sector this research undertook Eco-compass analysis, applying the Pareto principle, FGI (Focus group interview) and user interviews.

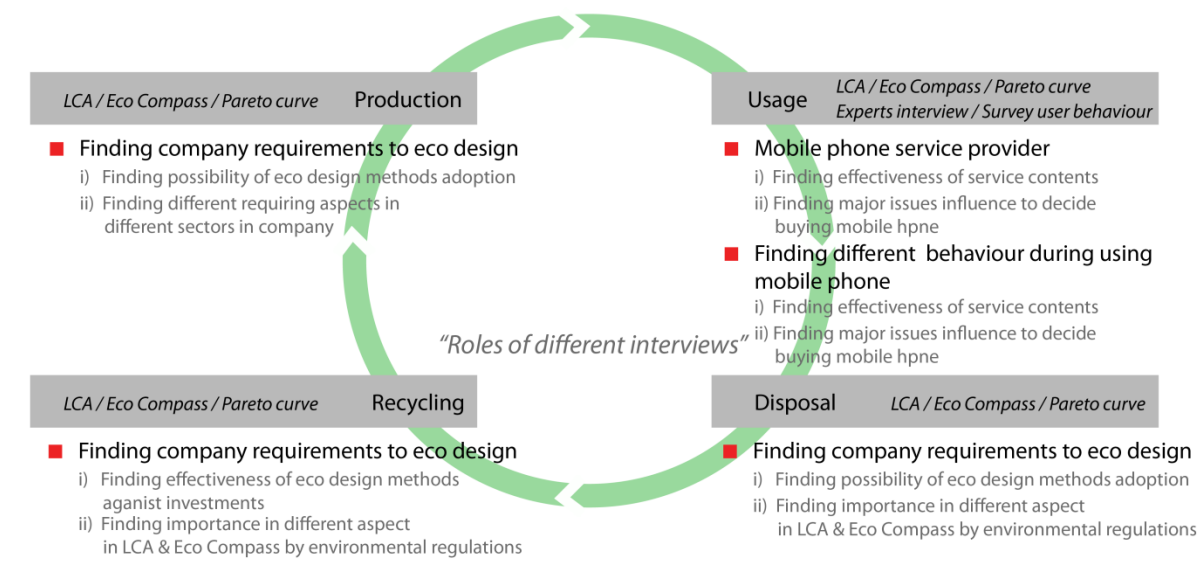
The reason of why the researcher adopted these research methodologies that firstly Eco compass has been used the most and widely to environmental engineering area and this methodology can compare the each fact by visual schematic approach. However, this methodology often significantly simplified the accurate LCA data, which is complex and symbolic data to ambiguous design data.

Second methodology is FGI, which has been used in UX design area. The advantages of this methodology are i) can get the significant voices of different industrial fields and ii) this can deduct the reliable background data comparing to other interview base approaches however the difficulties of this methodology are i) difficult collecting the experts at once for deducting effective interview and discussing results and ii) all the targets of interview require the similar or the same level of position for interview balancing.

Finally, Pareto principle is for comparing the efficiency against investments in different aspects. Therefore to compare the each eco design method in business

perspective, the researcher adopted this methodology to find the merit in different phase of investments.

These experiments work in different areas (see picture 8.1).



Picture 8.1 Different interviews' roles

This figure demonstrated that have been explained and defined the various difficulties, barriers and ways of approach in chapter 5 about research methodologies such as LCA, Eco compass, and Pareto principle. These all methodologies deducted the significance environmental value through previous chapters and this chapter shows new business opportunities by considering environmental efficiency against scale of investments.

Through this implementation, the author will do comparison analysis of level of possibilities in business opportunity and environmental aspect. Therefore this chapter will undertake the background research via different group of interview targets.

The interviews have been undertaken in four different areas.

User group interviews targeted mobile phone users as well as various employees who work related to the mobile phone industry in marketing, sales and manufacturing because these interviews need to show a wide range of issues in decision making for buying, developing mobile phones and mobile phone usage behaviour. The author implemented a balancing of demographic structure in roles, genders and age groups in these interviews.

The author considered that decision-making for buying new mobile phones will be a significant factor, which is reflected in consumers' and manufacturers' key issues, therefore the author undertook interviews to understand relationships between service providers' marketing approaches and design and also finding the impacts on decisions through environmentally friendly factors. Hence, these will provide background data for rating eco design importance from a company perspective for implementing further research.

Each interview will provide guidelines for developing an importance ranking in LCA and Eco Compass through different sections of a product lifespan to generate research results and also the interview results will compare the importance of international environmental regulations, which impact on the Korean mobile phone industry through influencing global major mobile phone markets.

8.1 Aim of the interviews

The interviews (which have different focus / tasks) were undertaken in this research and consisted of mutual links step by step to find solutions regarding eco design methods and effectiveness from different perspectives. The interviews look at user groups who use the product at different times and usage levels, average pattern of consumption and decision behaviour and also considering manufacturers to find ecological attractive factors and possibility within eco design from a company perspective.

8.1.1 Aim of user group interviews

The purpose of this interview can be divided into two phases. Firstly, interviews will present consumer demands and potential needs which will provide the background for developing eco products from a company perspective. The contents of this will be i) to present relationships between the importance of eco factors and purchasing, ii)

eco design factors stimulating purchasing and iii) ranking the importance factor for decision making.

Secondly, this interview will provide fundamental data for analysing energy consumption. This will show the results for the average amount of energy consumption and charging time and the researcher will apply these results to LCA to find average amounts of Korean mobile phone energy consumption and usage.

8.1.2 Structure of implementing interview

The interviews were implemented for focusing on the different purpose in the step table. To undertake user group interview, the author conducted to balance in gender, occupation and aging for example, it was considered sorting by occupation that could be influenced to mobile phone development or distribution. This also interviewed the subjective questions for finding the using mobile phone because the researcher thought this group has the different requirements to the current mobile phone and service.

In case of finding general user group, the author leaded the interview to find the pattern for distinguish heavy and light user. These will be the significant data for analyzing the consumer behaviors and calculating energy consumptions and also the results of this aspect will be two different types of scenario in end of this section.

8.2 Undertaking user group interviews

8.2.1 Demographic factor of interviews

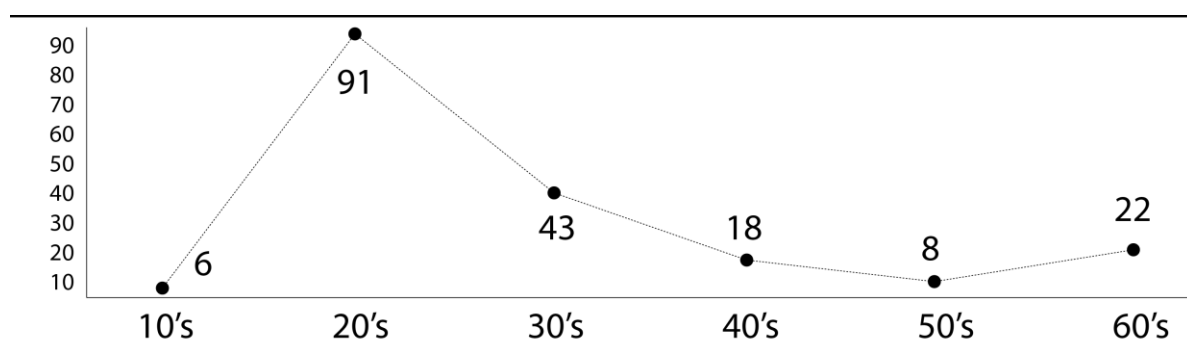


Figure 8.1 Demographic factor (sort by aging group) for user group interview

In this chart, the interview took two hundreds samples and one hundred eighty eight replied with most interview answers concentrated in the twenties.

The interviews recorded 94% response rate and the 20's took 45.5% of the total. The second largest group is the 30's and this group is taken 21.5%. The smallest group is the teenage group because they do not have economical capability to purchase a mobile phone on their own. This group also do not have long mobile phone usage experience.



Figure 8.2 Demographic factor (sort by gender) for user group interview

This chart shows the proportion of repliers by gender. The males consisted of only one-third of all and the female group were two thirds. The reason for this can be assumed to be that more women work in the mobile phone design area in Korea than men.

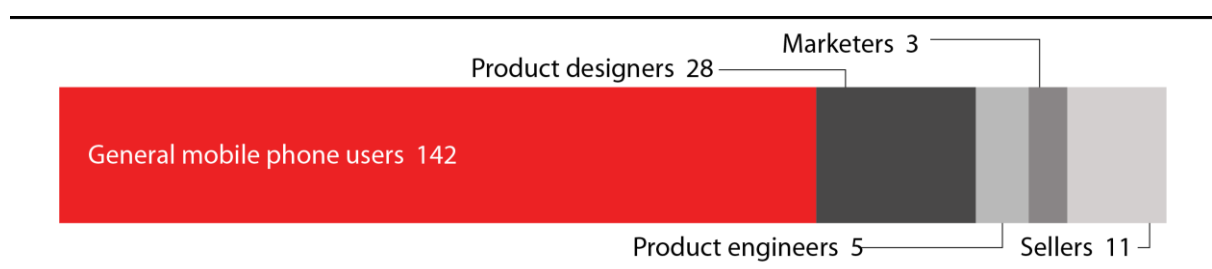


Figure 8.3 Occupation factor for user group interview

Most answers were from the general user group and the product designer group followed. Features of the general user group are i) normally they have confidence to use new types of products and some groups think that using new mobile phones is very important to show off one's fashion trend in their society. ii) They show us their

obvious character when using, buying and carrying phones as different age groups.

iii) The general user group also shows different regard to contracts than younger groups, who appear very sensitive re mobile phone design and functionality, however the first concern for buying a mobile phone in the over 30's group is payment and after services.

8.3 Results of user group interviews

- **General questions regarding Mobile phones and Mobile phone contracts in Korea**

1) Considerations before buying

As the development of IT and communication technology continues, consumers can gather information easily before buying a product. A mobile phone has obvious product characteristics that primarily consumers carry day and night, so consumers choose a mobile phone much more carefully. A mobile phone is one of the most complex products on the market and they are not the same as TVs or refrigerators. A mobile phone demands a contract, generally Korean mobile phone contracts are based on between sixteen and twenty four month's with complicated documentation. Sometimes this also requires a guarantor when the person is under eighteen years and wants to buy a mobile phone in Korea. Therefore many consumers do research regarding price, functionality, design etc.

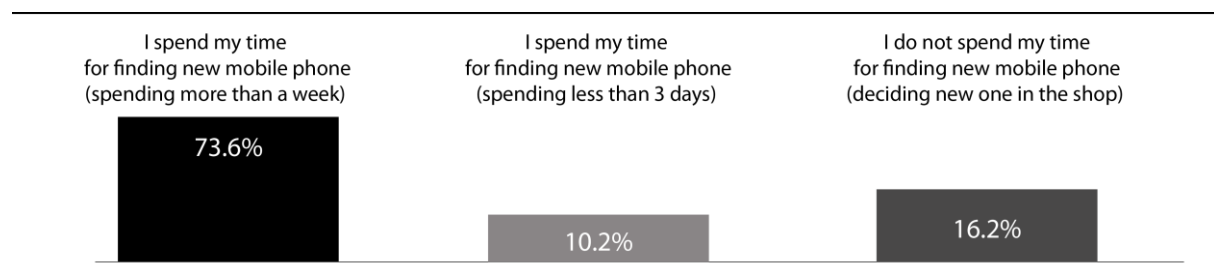


Figure 8.4 Rate of research before buying a mobile phone

This table shows rates of research before purchasing a mobile phone, 73.6% of consumers do research and between the 10's and 30's groups show obvious signs

of this. Comprehensively, this sharply increased by the mobile phone price rising and this shifting price range influences the changing mobile phone paradigm from short-term expectancy to long-term lifecycle.

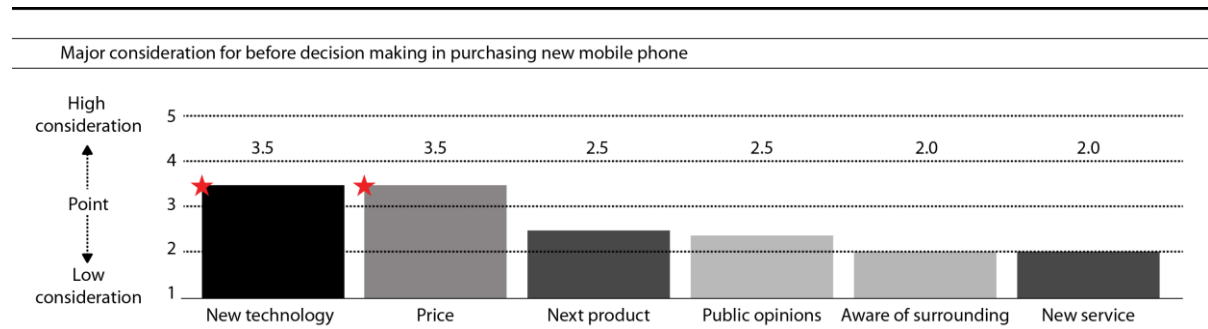


Figure 8.5 Consumer's major consideration before buying a mobile phone

Figure 8.5 shows a list of consumer concerns before buying mobile phone. Most consumers think about product qualities and other people's preferences. Product quality is the most fundamental fact in persuading consumers with "new technology" and "price", which are traditionally powerful factors in electronic product development.

Consumers are also concerned about others people and the quality of the next product. For instance, shifting the product paradigm gives positive and negative influences to the consumer. At the end of 1990's, the mobile phone market had a huge evolution through the convergence concept, which focused on just phoning to moving to additional functionality such as the digital camera. However consumers who just bought the older version of the mobile phone complained to the manufacturers.



Picture 8.2 Changing the buying paradigm (SNS: CYWORLD (Korea) / Facebook (US))

A new type of product also creates new social and technology trends. “CYWORLD”, which is the biggest SNS in Korea was created in 1994, has influenced the convergence of the digital camera and Internet technologies to mobile phones and for undertaking new user demands. When appearing, SNS (Social Network Service) provided a new opportunity that changed the purpose of using mobile phones from communication devices to total mobile devices through convergence with other technologies.

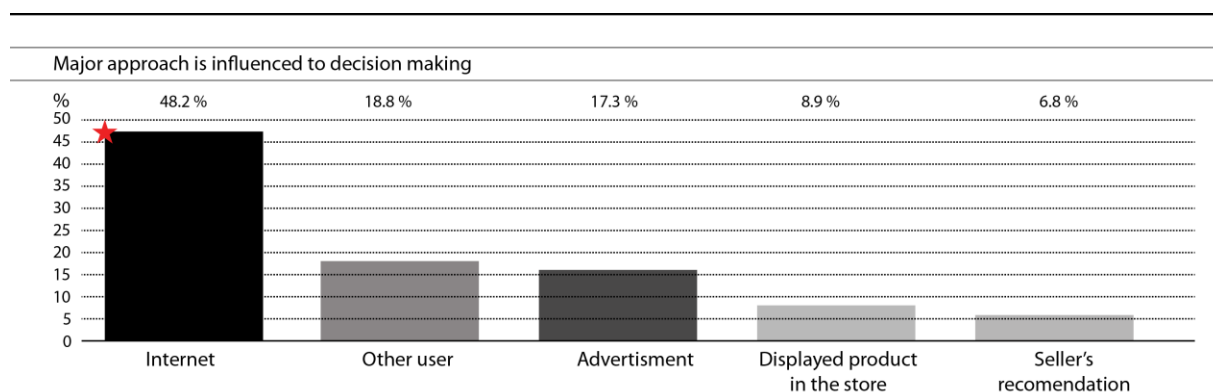


Figure 8.6 Major information factors are influencing to consumers

Developing ICT (Information Communication Technology) brought a new paradigm, more information and faster networks and therefore more information before buying

products and this naturally accelerated comparison of mobile phones as well as other products.

In Figure 8.6, Internet access is the biggest method for collecting information. 48.2% answers replied with this, which was almost half of the reasons from the users. This also illustrated the importance of moving research for devices from off- line to on-line.

The interview results provide background data for estimating the possible development direction for eco design methods, especially the various requirements in the marketing sector, when assuming the appropriateness of eco design methods. These results can also estimate turning points from traditional marketing approaches to a new paradigm marketing mix that transfers from four Ps (Product, Place, Promotion and Price) to four As (Anywhere, Anytime, Anyway and Any product) when applied to on-line marketing.

Summary

- Consumers research when buying new mobile phones and use various ways to collect information. The ICT era brought not previously available information to the consumer.
- Service or external factors for products has been significant on many occasions, PR and marketing decide which products will be successful or not.
- On-line information has been a more important value factor rather than Off-line information.

2) General question about using a mobile phone

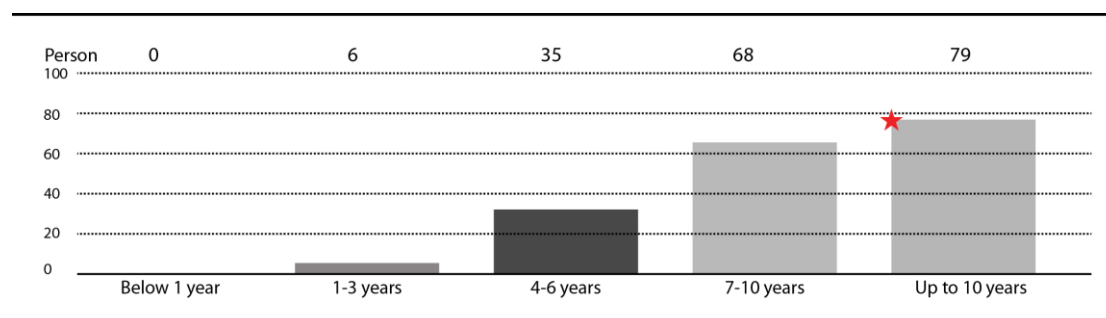


Figure 8.7 Survey to experts on mobile phones

This Figure shows experience when using mobile phones. A mobile phone user in the group one to three years are almost all concentrated in the teenage group. There are 147 people who have over 7 years' experience on phones. However this table cannot define that the older age group is more expert than younger age group because questions did not consider learning abilities and the frequency of exposure to social trends.

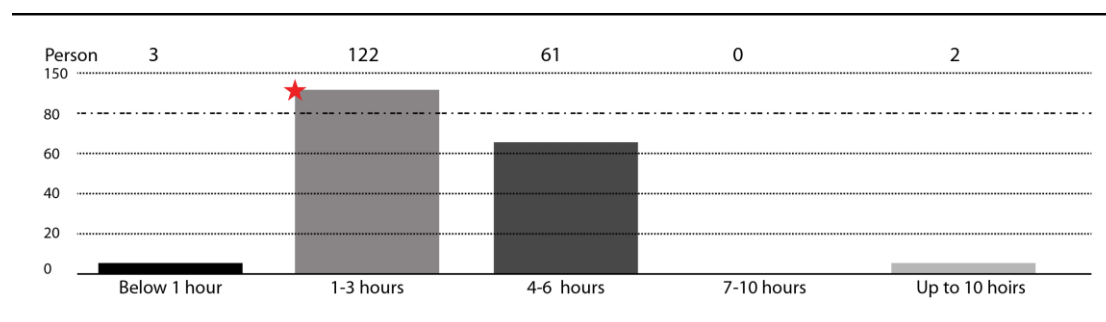


Figure 8.8 Survey for average usage time (per a day)

Regarding the question “how long do you use your mobile phone?” most people are located in the 1-3 hours group. This result included all mobile phone functions such as phoning, Internet access, SMS, MMS and other functions. The result can be divided by gender and age, the female group are more concentrated in the 4-6 hours group and they mostly use SMS and the phoning function and male group is more concentrated in the 1-3 hours group and they use phoning and entertainment. This research will gain data on amounts of average energy consumption and major consumption behaviour through analysis of LCA, based on the interviews.

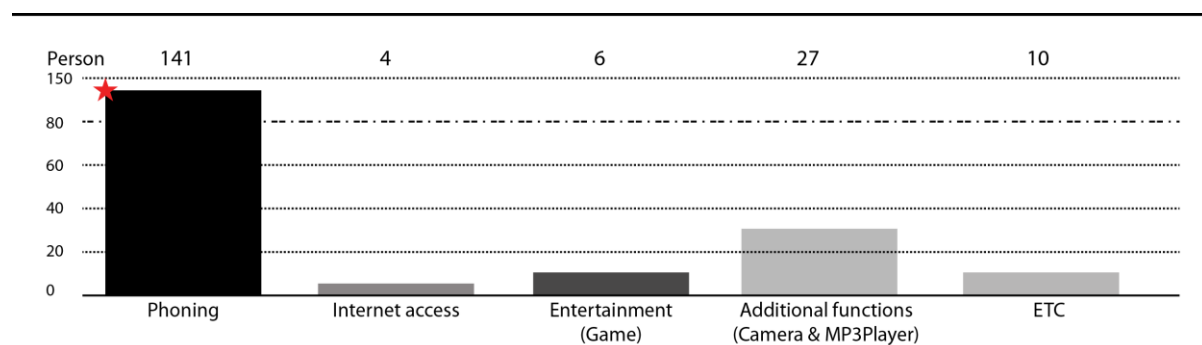


Figure 8.9 Survey for average usage time

The question was “what is the major functions for you?” and most respondents answered phoning (141%) and using additional functions followed (27%). Although this result has not taken enough samples to define however in Entrainment, gained 6 % of answers and were all male and in the young age group, in contrast additional functions (camera) has 27% of answers, and were all in the young female group, hence, this figure can illustrate that i) using traditional demands of the mobile phone was the biggest issue but ii) major users of other functions can be divided by gender and age.

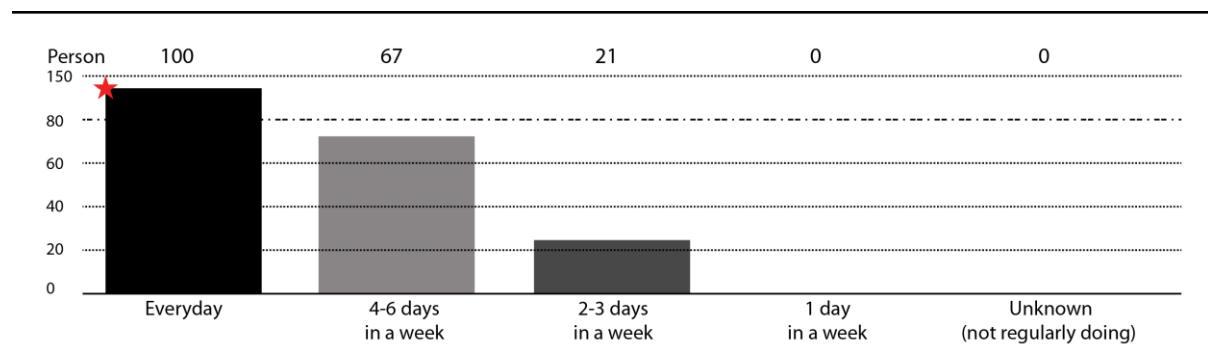


Figure 8.10 Survey for average battery charge period

Figure 8.10 shows the frequency of battery charging. 53.1% of answers replied that they charged their mobile phone battery every day and 4-6 days in a week followed (35.6 %). However, this survey has several variable factors such as mobile phone models, age and user behaviour, and it was also influenced by the capability of the mobile phone battery. In this survey, 88.8% of users charge the battery more than three days per a week, which means a huge amount of electrical consumption is wasted.

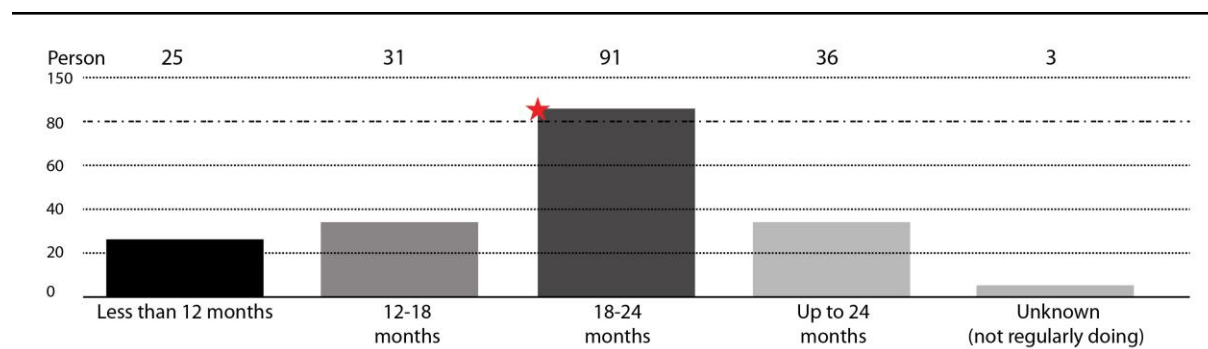


Figure 8.11 Survey for average mobile phone lifespan in Korea

Figure 8.11 explained the frequency of changing the mobile phone in Korean mobile phone users.

In this survey the largest group is located between eighteen and twenty four months (91 respondents). The reason for this may be because i) contracts for Korean mobile phone service providers are based on two years and this expiry date stimulates the consumer directly even for those who have not yet considered a new phone. ii) Older age groups are divided into two different groups, which are an early adopter group versus longer period mobile phone user. This result can be analysed with the first group working in a more sensitive area by trend such as designers and marketers, moreover these type of occupations require capabilities to understand trends such as early adopters, On the other hand, the other group has no concern for new technologies moreover, some of this group of people accumulate stress with new technology products.

Summary

- Over 70% of customers change mobile phones through contracts.
- Mobile phone usage behaviour showed different results for different gender and ages.
- Younger ages and male groups use mobile phones as entertainment devices and female group mostly use SMS rather than phoning. The older group and males mostly use phoning and functions related to work and females answered that they mostly use it as a communication tool.
- Respondents answered that batteries still have serious electrical waste problems.
- Most users use mobile phones for 3 hours per a day and the major objective is phoning.

8.4 Undertaking expert group interviews

8.4.1 General questions about using a mobile phone

Generally a mobile phone contract consists of 5 steps. When reviewing picture 7.14 there are 3 pages of the contract from KT (Korean Telecom), which is one of the biggest companies in Korea and this document has 5 sections.

The image shows a Korean mobile phone contract from KT (Korea Telecom), divided into five sections labeled A through E. Section A is '신규/명의변경' (New/Name Change), Section B is '요금/결제' (Rates/Payment), Section C is '개인정보 수집/이용·위탁·재광 동의서' (Personal Information Collection/Use/Entrustment/Relinquishment Consent), Section D is '법정대리인 동의서/대리인 위임장' (Consent of Legal Representative/Power of Attorney), and Section E is 'SHOW 쇼킹폰서 골드형 / 1-월' (SHOW Shocking Phone Gold Type / 1-Month). The contract includes fields for customer name, phone number, and various service options.

Picture 8.3 Contract from KT (Korea Telecom), is Korean mobile phone service provider

Section A is general information about customers.

Section B regards payment. There are 5 different conditions and each method has a different service (this condition is different by type of mobile phone and service provider). Normally this condition is decided by the proportion of free call and SMS, for example 500 minutes free call and 100 free SMS is cheaper than 600 minutes free calls and 50 free SMS. This part is one of the most competitive service provider conditions and also directly impacts the consumers in deciding which mobile phone and service provider to choose.

Section C demands the agreement for payments and using the services.

This part can be automatically connected to other services or goods, which has partnerships with mobile phone service providers and particularly the fact of 'Using

personal information' is often a disadvantage to customers, for example leaking confidential information through hacking the networks.

Section D is for a legal representative for under 18s. In Korean broadcasting and wireless communication law, under 18s cannot sign contracts without a legal representative or guarantor.

Section E, E1 and E2 are all about other services, which are related to the mobile phone service.

In the case of this research, the significant part is section C which mentions compensation and various options. Since WEEE came into effect, manufacturers have to improve recycling rates for maintaining production and section C shows the compensation re collection of waste mobile phones. This is the positive way to increase collection rates through collaborations between manufacturers and service providers to effectively deal with international environmental regulations and also this can lead to consumers to participate in environmental activities through supporting compensation.

Therefore this can be exemplified in presenting how environmental regulations can affect customers and what type of issues or policies do the manufacturers undertake to deal with international environmental regulations, moreover this can show the example that various eco regulations have impacted Korean mobile phone markets.

Summary

- Mobile phone contracts in Korea consists of 5 sections and this is contained directly or indirectly to mobile phone services.
- The most important line in the contract is the payment and service period.
- KT, SKT and LGU, which are the biggest service providers in Korea have their own contracts, however there is not much difference in them.
- The contract can be divided by target and market position. For example, Korean mobile phone service providers prepare various attractive offers for high school students such as free phones or other promotional programs.

8.4.2 Questions regarding mobile service contracts

On many occasions, current product lifespan has been decided by mobile phone service contracts. Many Korean people have shown the early adopter tendency (Korean customers ranked 2nd position for frequency of change period; 6, 2013 Korea Gallup research) hence two years expiry date, which is an average contract period which impacts changing / upgrading mobile phones.

Therefore for such reasons, service contract periods have impacted mobile phone lifespan and moreover this issue also influences various factors for purchasing such as decision making on the model of mobile phone and service provider.

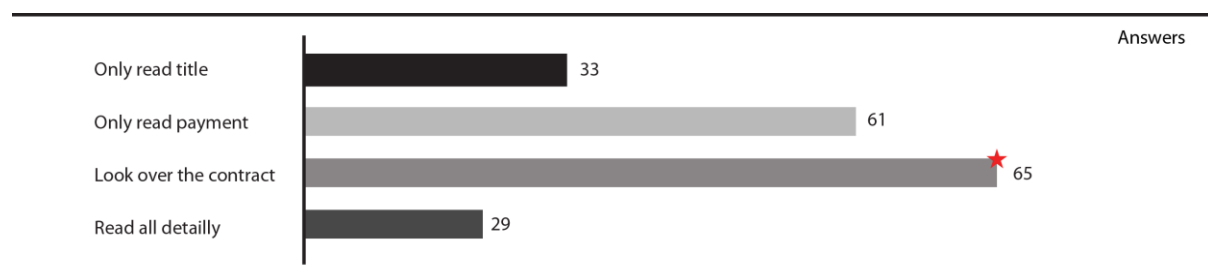


Figure 8.12 Survey about user behaviour when reading mobile phone service contracts

50% of users read the entire contract and 1/3 of all respondents read only payment options / plans. This shows that payments are the most significant decision making factor currently.

Younger age groups (teenagers and twenties) mostly 'only read headlines' and 'only read payments' because this group does not have experience signing contracts and also most customers in this group cannot afford the mobile phone on their own.

The fifty's and sixty's group paid close attention to signing contracts and they understood contract terms and also understand they could make mistakes through carelessness such as utilisation agreements and personal information usage policies.

Namely, mostly new mobile phone users have made the contract looking at the context of contract not accurately especially teenager group, who does not have enough social experience, could not understand the contract languages.

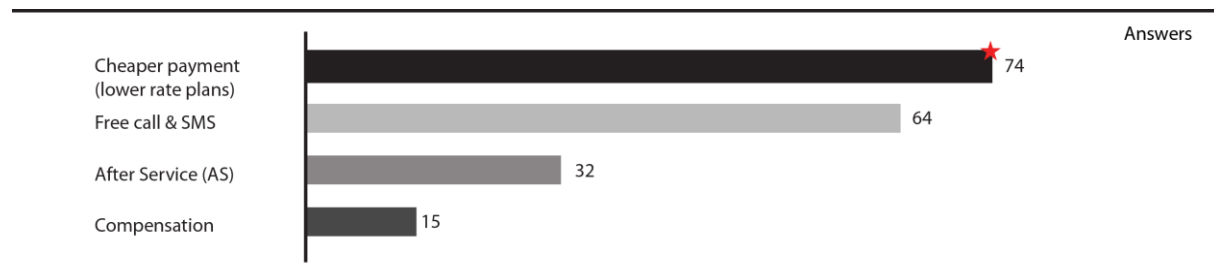


Figure 8.13 Survey regarding decision making reasons

The price for using the service is the most important factor in making decisions. In the responses, 74 respondents (39.4%) answered that the price or plan for the discount is the most attractive factor in the contract. Free call and SMS followed with 34%, however smart phones, which are based on Internet technology made changes for various applications (Apps), which can connect, to other people through free Internet.

‘As guarantee’ and ‘Compensation’ have increased due to user dependency on the mobile phone and as technology development advances, therefore people feel that they cannot live without mobile phones now. These results can distinguish different age groups for specific answers. Younger groups (teenager and twenties) who mostly pay service charges through their parents, are more concerned with price and free services such as free calls and SMS, however the thirties group, who started work, considered the value of after service and additional options more important.

That can provide the background data for developing environmental friendly mobile phone to aim the clear target for instance; aging group requires saving the mobile phone price by using reduced function method and younger group can be applied energy saving method for using longer battery.



Figure 8.14 Survey regarding user behaviour recognising remaining contract periods

116 respondents (61.7%) answered that they recognised their phone contract expiry dates, which was the majority. The main reason for recognition was i) desire to purchase next generation mobile phones and ii) wanting to change the service provider or mobile phone through dissatisfaction of services or mobile phones. These answers are based on the quality of service and mobile phone and most answered that services have to improve especially payment methods and service providers needed to provide identified services to keep the regular customers on board.

In this survey the expiry date is the strongest reason for changing mobile phones, therefore such facts stimulated the development of customised features for Korean mobile phone users.

That means applying and hybrid eco design methods with outside facts such as marketing and social trends can address longer lifespan of mobile phone. And also mobile phone contract need to be adjustable period and price to reflected user's situations.

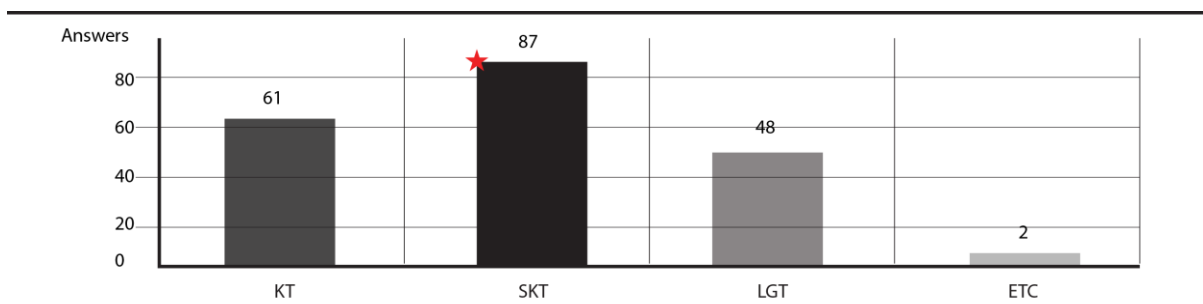


Figure 8.15 Survey regarding user behaviour and choosing mobile phone service provider

The Korea mobile phone service market has been controlled by 3 major companies; KT (Korea Telecom), SKT (SK Telecom) and LGT (LG Telecom). These companies had very different approaches on entering the market initially.

KT is a public enterprise and was established in 1981. This company was positioned 2nd in market share until 2009, however they succeeded in importing the I-phone in November 2009 and their position changed to 1st. The major role of KT was providing network systems and constructing facilities. SKT was established in 1984. This company initially used CDMA technology to realisation and DMB services. They ranked 1st from 1990's to recently however they couldn't deal with the new mobile phone paradigms, which delivered the smart phone onto the market. LGT is a subsidiary company under the LG group and this company is only connected to their own manufacturers. LGT started much later than the other major companies, therefore the market share rate is much smaller but their position has extended rapidly through the use of new high technologies and their global distributors.

The responses are shown by different age groups; 65% of LGT users were in the teenage group (LGT 65% / SKT 32% / KT 3%). In contrast, forty's and fifty's groups preferred KT (75%), SKT (25%). It may appear that LGT, who came into business later than the others therefore this company provided advanced and distinguished services for teenagers such as flexible payments, cheaper conditions and regular marketing events, however KT and SKT have appealed to the older generation through service reliability and successful growth of their business.

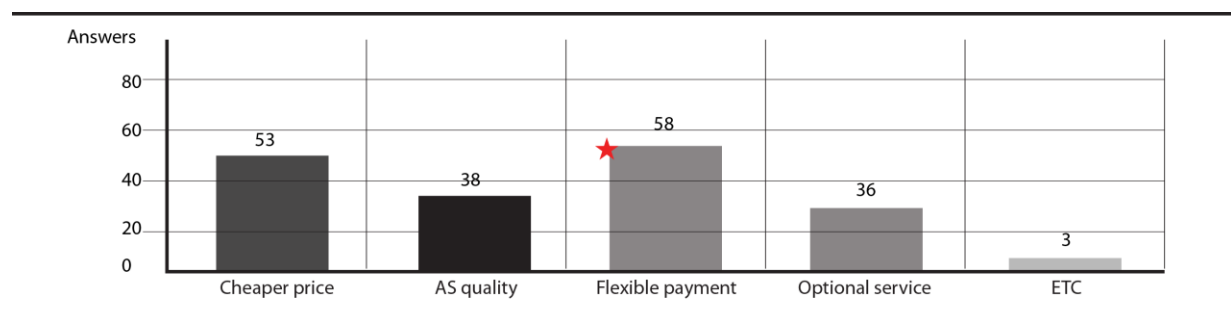


Figure 8.16 Survey regarding reasons for choosing mobile phone service provider

The results show various reasons for standards in selecting the mobile phone provider. 111 answers from 188 respondents replied that price and payment methods are the strongest decision makers however, 77 respondents answered additional services and after service (AS) quality are the most important factors. 34 respondents were male within 36 answers re; optional service importance and these respondents considered using the Internet and entertainment as more important. In contrast, 32 female respondents replied that AS service was most important, this female group were concerned with repairs and compensation complexities re poor service. Teenagers converged on flexible payments because most answers in this group were re economic pressures and over 60% of answers within this group stated that payment was paid by their families.

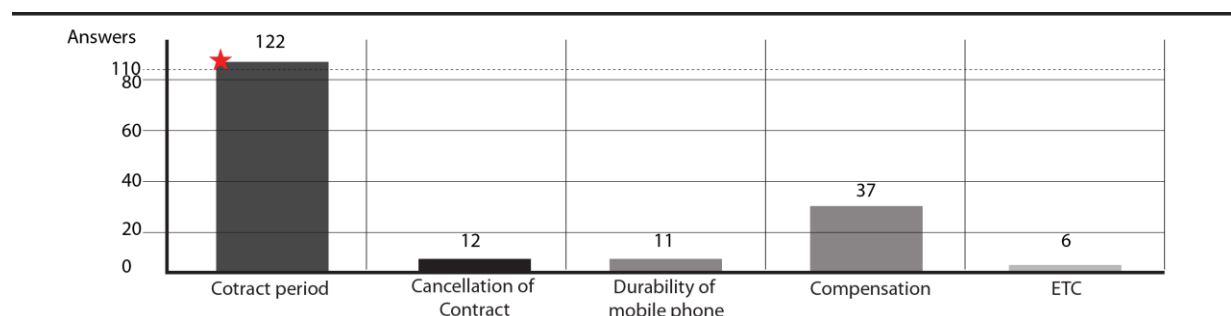


Figure 8.17 Survey regarding user concerns after completing contract

As mobile phone prices rise and the mobile phone functions become more useful for the customers, people's concerns and proportion of dependency have increased. Contract periods, which has the largest influence on purchasing is generally between 18 and 24 months, however the period has been extended to 36 months with increasing mobile phone prices by high pricing policies from manufacturers. As extending the contract period increased users' dissatisfaction these issues stimulated improvements in various services such as compensation and provides different types of repayment.

Summary

- Over 70% of customers are influenced by changing mobile phone contracts.
- User mobile phone behaviour has shown different results through different

gender and age groups.

- Some lines relate to environmental policies in the service contract however there are self-regulating compensation policies for collecting waste mobile phones.
- The contract period and price for using mobile services gives the largest impacts on decision making, however satisfaction rates for customers have decreased when comparing current services to increasing mobile phone prices through high price policies from manufacturers.
- The environmental responsibilities of providers have increased through international environmental regulations particularly WEEE and RoHS, which focus on manufacturers' social and environmental responsibilities. However, collection and disposal of mobile phones in Korea is voluntarily hence rates of waste mobile phone collection are limited to batteries and LCDs.

8.5 Questions regarding Eco friendly design methods

This interview question has two aspects; finding major decision factors in purchasing and demonstrating importance factors from an environmental perspective. For understanding environmental factors where consumers show interest, the author established indirect questions to understand and extract key issues from the eight eco design methods used in this research; material, energy, usability, functions, process, product lifespan, structure and recycling and developed the questions to reflect purchasing scenarios. Through this approach, it provided the importance ranking for eco consumer factors, which reflects eco design issues from a consumer perspective. This will help to develop potential purchasing factors with the integration of eco design methods and consumer insight.

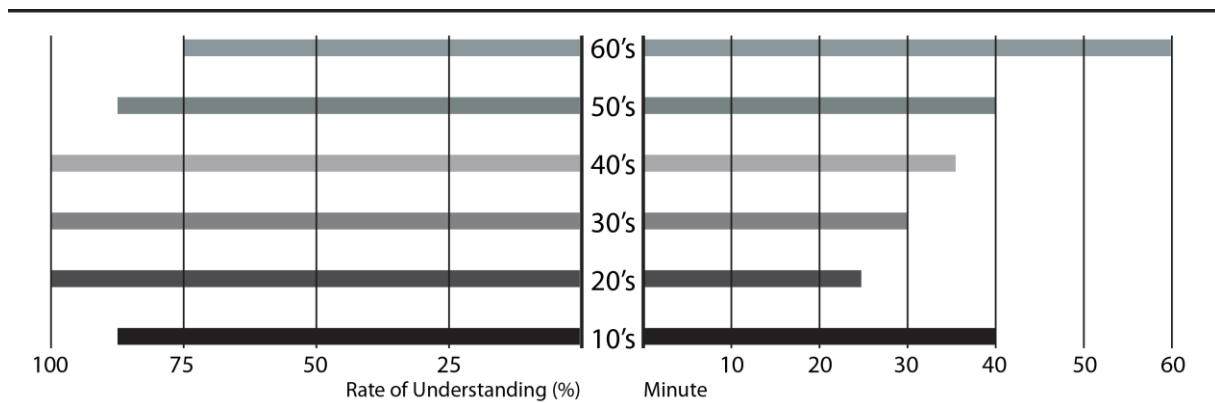


Figure 8.18 Survey regarding time spent understanding eco design issues

Figure 8.18 shows different understanding rates re eco design through comparison of rates of understanding against time spent. These interviews show how different rates of applying eco design issues within different age groups. To effectively undertake the interview, the author established indirect questions that were related to the eco design methods for example, 'ecological durability can extend product life span for 3 months or more', 'energy saving can save 3% of power consumption over current mobile phones', 'simplified product assembly structures can reduce disposal processes by 5%'. These questions are all related to each eco design method, which were used in this research and the author considered the balance of conditions in each question.

Figure 8.18 shows the understanding gap between 20's, 30's and 60's and in the case of 50's and 60's, the participants had more difficulty particularly with simplifying assembly structures and ecological approaches. Moreover, 45% of participants were confused with recycling and reuse answers during the interview, respondents used 'recycling waste components in new products which would not be an attractive factor'. In contrast, teenage groups interpreted eco design from their perspective for instance, despite establishing functional priority (related to the reduced function method) and saving waste energy, which may impact the market because younger age groups follow new technologies and functionality even when not using many general functions.

The teenage group required a longer time to understand eco design issues rather than the groups of 20's, 30's and 40's. With the rating of understanding, some participants in the 60's group had experience of mobile phone companies so their answers increased their understanding. The groups of 20's and 30's who have higher concerns regarding eco issues and eco design also had opportunities to understand these issues through various mass communications, which were positive.

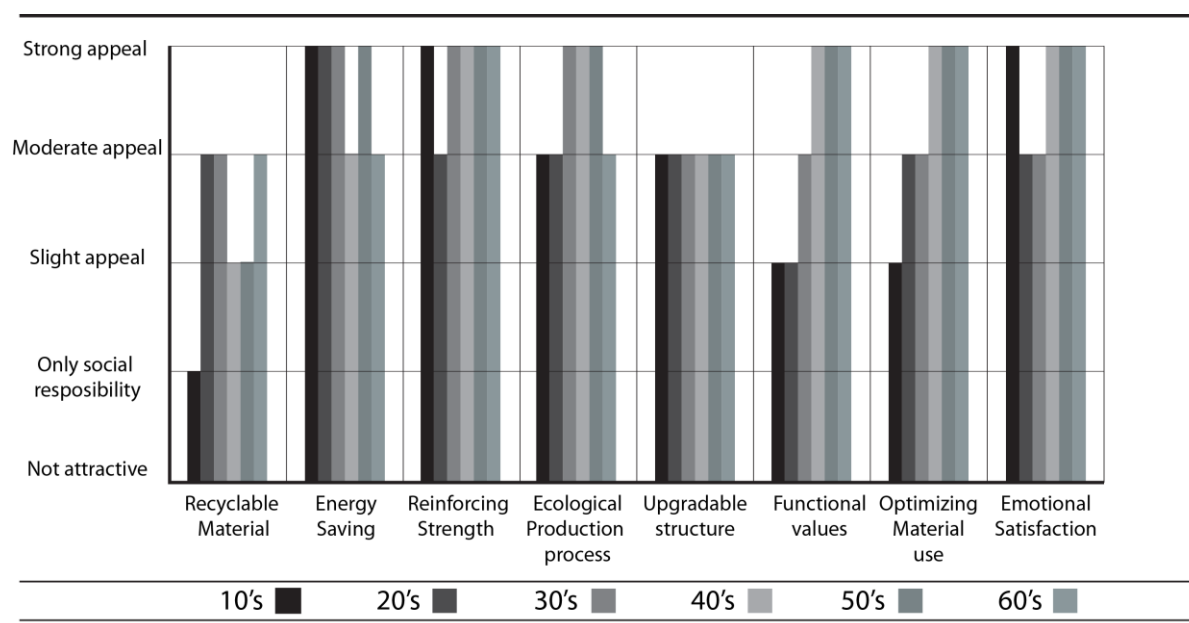


Figure 8.19 Interview regarding attracting mobile phones through different ecological factors

Figure 8.19 shows how purchasing is influenced by different eco approaches. This result, using recyclable material did not appeal to all age groups and reinforced the strengths of products highest sales position because the major reason reflected users' demands to use the mobile phones more safely during usage times rather than extending mobile phone lifespan.

The 60's group of participants appealed more to environmental issues rather than teenagers and 20's and 30's groups who showed preference, therefore applying eco design to product development for these age groups required finding certain factors and creating more attractive product values. The energy saving method strongly appealed to teenagers and the 30's group, who use mobile phones more than other

age groups, whereas the 60's group have not showed any purchasing preference in energy saving methods used. With the applied upgradability method, which was the easiest eco design method for the industrial designers, this showed lower appeal to costumers over other eco design approaches because it gives emotional stress through longer use of the same model. Older age groups (50's and 60's) replied positively to material optimisation. These groups have more concerns regarding health issues and environmental preservation hence, these groups wanted to use natural materials and less toxicities in the products.

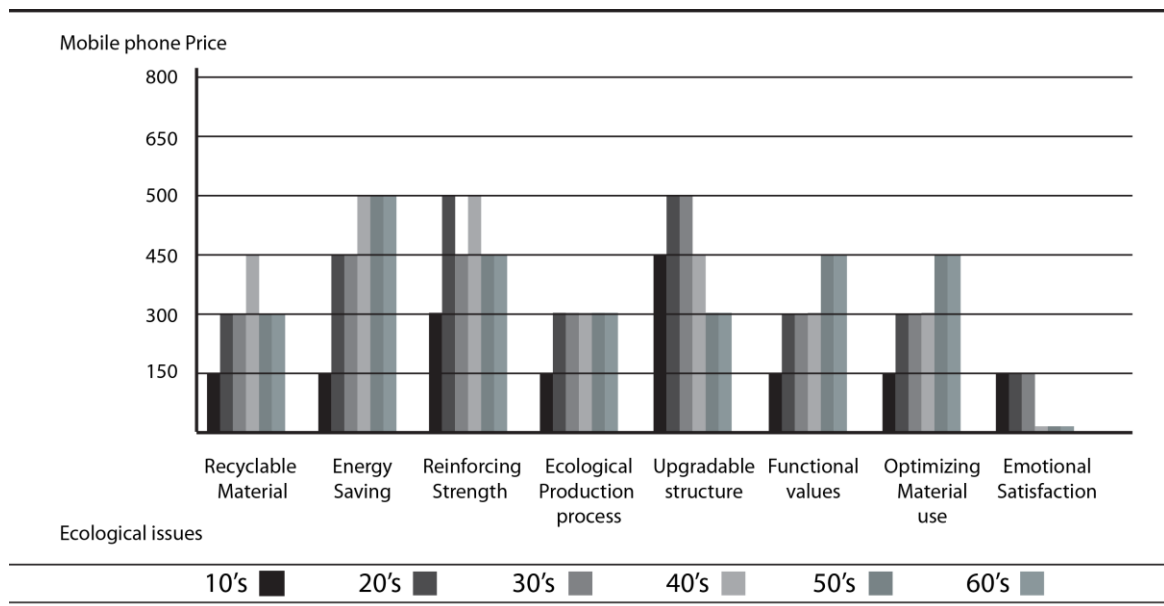


Figure 8.20 Interview re spending limits on eco issues in mobile phones

In figure 8.20, the consumers' reaction regarding eco products developed through eco-friendly production processes did not effectively appeal over other environmentally friendly approaches. Through this fact, emotional facts did not appeal to consumers over functional achievement and the older age group did not give any positive feedback re the environmental issues.

The 60's group thought the balance between economic and environmental benefit; less energy consumption and shorter charge times would generate better economic and environmental benefits.

The teenagers group showed sensitive reactions regarding energy consumption however, this group generally were against paying for environmental issues through higher economic costs when purchasing mobile phones. This age group did show positive responses ret upgrade structures and componentry as this type of approach can realise the possibility of customising mobile phones. In summary, older age groups considered the economic benefits for environmental issues however, the 10's and 20's groups wanted investment for customised value (upgradability) such as online social identity and maximised functionality.

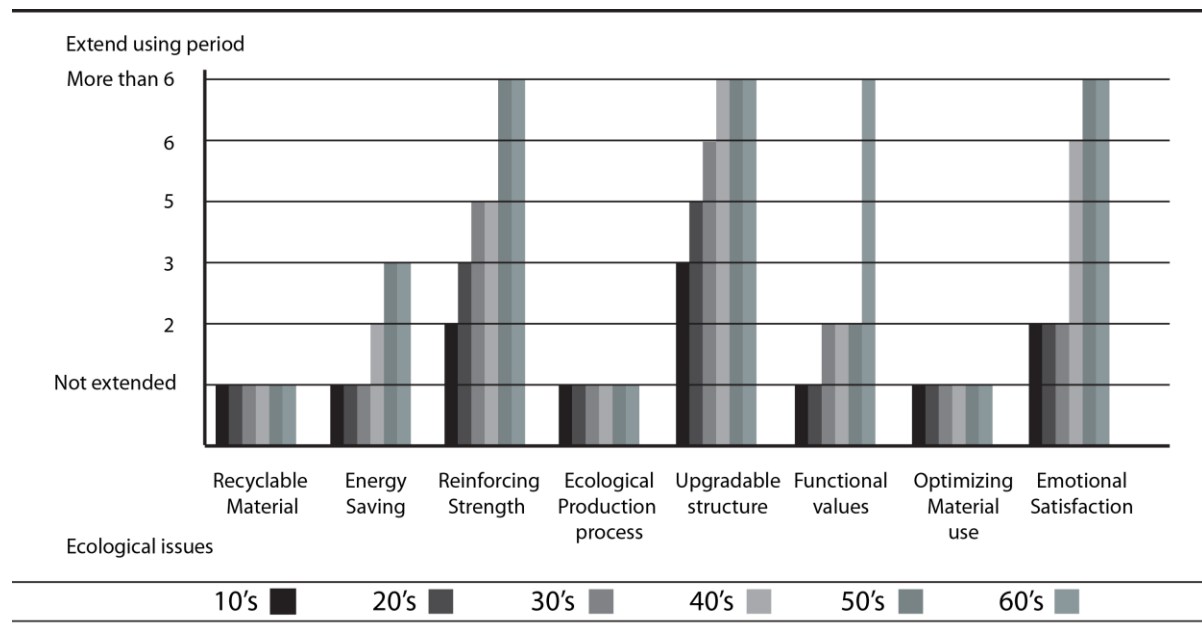


Figure 8.21 Interview regarding extending mobile phone usage periods through different eco issues

In figure 8.21, users stated that the upgradability method could be the most effective tool for extending product lifetimes. Answers mostly stated that the upgradability method has very powerful factors to appeal to customers, if the products have upgradability then obsolesce reduces and so do repair times, this fact will extend the effective product lifespan. While engineers asserted in the case of optimising use of materials in ecological production processes and using recyclable materials did not appeal to consumers compared to other approaches, therefore those approaches could not extend product lifespan through user functionality or emotional satisfaction. To use those methods requires considerable direct benefit for users. For emotional satisfaction, the older age groups require more satisfaction compared to younger

groups despite the product providing better satisfaction for users. However, functional satisfaction was not well supported, in particular with younger age groups who would not use the product for any longer, therefore reducing possible product lifespan.

8.6 Findings from user interviews

In conclusion decision making for purchasing mobile phones was still through functional satisfaction, with price ranked the highest priority. This means that although there are some design successes in the mobile phone industry e.g. Apple i-phone. The most influential function was marketing through Internet access and traditional advertisement. These two approaches had a 30.9% gap (section 8.3) and moreover this gap will extend with increasing amounts of Internet users.

With average mobile phone usage time (see figure 8.9) the largest user group was 1-3 hours users (122 / 188) most users using the mobile phone for phoning. Battery charging was carried out mostly daily (figure 8.10) and as increasing amount of smart phone users this will also increase.

Korean mobile phone users change mobile phones on average between 18 and 24 months, according to the GATT report this frequency is the fastest globally. During the interviews younger age group had shorter satisfaction re mobile phones, however due to contract costs, this group changed mobile phones when the contract finished.

Korean mobile phone service contracts started to reflect environmental issues (section 8.4.1) however this section only related to collection of waste mobile phones for recycling by volunteers.

With questions regarding user awareness for environmental issues, generally mostly respondents selected answers related to their own economic benefit rather than focus on environmental or social benefits.

1	Attractive environmental issues within the mobile phone							
	Recyclable material	Energy saving	Reinforcing strength	Ecological production process	Upgradable structure	Functional values	Optimizing material use	Emotional satisfaction
10's	1	4	4	3	3	2	2	4
20's	3	4	3	3	3	2	3	3
30's	3	4	4	4	3	3	3	3
40's	2	3	4	4	3	4	4	4
50's	2	4	4	4	3	4	4	4
60's	3	3	4	3	3	4	4	4

Table 8.1 Results of user interviews re attractive environmental issues within the mobile phone industry

* Number 4 is the strongest appeal / 3 moderate appeal / 2 slight appeal / 1 only social responsible / 0 not attractive

Durability and energy saving issues were selected for their strongest appeal and using recyclable material was the weakest appeal to customers in these interviews. The reason for this was current environmental issues have to reflect users' general demands and using recyclable material or optimising material use are based on a very narrow focus.

2	Limitation of spending money for environmental issues in mobile phone							
	Recyclable material	Energy saving	Reinforcing strength	Ecological production process	Upgradable structure	Functional values	Optimizing material use	Emotional satisfaction
10's	1	1	2	1	3	1	1	1
20's	2	3	4	2	4	2	2	1
30's	2	3	3	2	4	2	2	1
40's	3	4	4	2	3	2	2	1
50's	2	4	3	2	2	3	3	0
60's	2	4	3	2	2	3	3	0

Table 8.2 Result of user interviews regarding limitations in investment for environmental issues for mobile phones

* Number 4 - 600 pounds / 3 – 450 pounds / 2 – 300 pounds / 1 -150 pounds (GBP)

The limitation for environmental costs was 600 pounds and this investment included the mobile phone price. The strongest factor was energy saving and upgradability and those two facts appealed but there was conflicting age group opinions. Emotional facts showed the weakest factors particularly in 50's and 60's consumers, who did not consider the environmental emotional factors.

3	Extending mobile phone usage time through environmental issues							
	Recyclable material	Energy saving	Reinforcing strength	Ecological production process	Upgradable structure	Functional values	Optimizing material use	Emotional satisfaction
10's	Not extended	Not extended	2 months	Not extended	3 months	Not extended	Not extended	2 months
20's	Not extended	Not extended	3 months	Not extended	5 months	Not extended	Not extended	2 months
30's	Not extended	Not extended	5 months	Not extended	6 months	2 months	Not extended	2 months
40's	Not extended	2 months	5 months	Not extended	More than 6 months	2 months	Not extended	6 months
50's	Not extended	3 months	More than 6 months	Not extended	More than 6 months	2 months	Not extended	More than 6 months
60's	Not extended	3 months	More than 6 months	Not extended	More than 6 months	More than 6 months	Not extended	More than 6 months

Table 8.3 Result of user interviews re investment limitation for environmental issues in mobile phones (usage times)

Using recyclable material, ecological production processes and optimising material use did not appeal to consumers effectively and the reasons for this for this method was that it did not any direct benefits for users. Through these interviews the author found that to apply eco design methods for the mobile phone development requires the factors for direct economic or functional benefits for customers. Moreover according to these interviews, the most effective approaches were upgradability and reinforcing strength, which corresponded with current market demands.

In conclusion, through the user interviews environmental issues have been more closely linked to economic principles, which are based on generating benefits and the environmentally friendly issues have shifted from conceptual approaches followed by market trend and social benefit, which is closer to TBL (Triple Bottom Line; principle of Sustainability). Furthermore, as the environmental issues become more popular this will be more segmented and sophisticated, much the same as traditional marketing and industrial principles.

8.7 Interview II (Focus Group Interview)

To find different importance in each area of in-house companies and investment perspectives, the researcher undertook expert interviews. The method for the interview was applied focus group interviews (FGI), where experts discussed and shared opinions from a variety of perspectives to generate more logical outcomes. By using this interview method, experts from different areas initially discussed sharing ideas and new opportunities for the environmental and then discussed new issues found during initial discussions. Through these interviews, the researcher will show the economic values and long-term efficiency in markets verse investments from the CEO's perspective, market impact and enhancing company reputation from a marketing perspective. The realisation of design results was applied to eco design methods and possibility of using these from an industrial designer's perspective and technology problems and also the possibility of using these methods from an engineer's perspective.

8.7.1 Aim of expert group interviews

8.7.1.1 Eco design methods in CEO's perspective

Eco design or green design has traditionally and historically been used as the tool for giving social pressures or as solutions to enhancing company reputation or changing a negative company image. However, since the 21st century, the paradigm for environmentally friendly design has become more of a core factor in deciding company survival. The company has to follow various social and market pressures to maintain trade and companies; particularly manufacturers should frequently expose the evidence that the company has undertaken environmental preservation efforts. During the interviews, CEOs asserted that IT or ICT technology developed, social and environmental issues have been essential factors in deciding market success and often rather than functional excellence through spreading information, communication management has been more important recently. Moreover, environmental issues included in a company's morality, philosophy, strategy and current state hence, consumers have used this standard to judge company values which may influence decisions re success or failure in early stages. In addition,

developing environmentally friendly products historically has had a small effect than the investors' expectations but usually requires huge investment. Consumers think environmentally friendly products do not do enough for effectively protecting the environment. Therefore environmentally friendly products have become passive projects and provided only limited opportunities to CEOs.

However CEO's negative perspectives towards environmental product development has changed through various eco design methods, which reduced production processes, simplified assembly structures and prioritised product functionality. These technologies applied to the products previously have historically magnified only economic benefits in the market. In conclusion, CEOs asserted that new eco design methods, which have different approaches have traditionally appealed to markets through different marketing approaches, therefore as environmental issues raise public concerns, these methods would have enough value for investment and also potential ability to attract consumers.

These figures are CEO's replies, which ranked eco design methods by different questions.

Task	1	What eco design method will be the most effective against investment?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	5	7	4	5	8	1	3	2

Table 8.4 CEO's reply re what eco design method will be the most effective against investment?

This table shows the most appropriate eco design methods for applying to the mobile phone development and for deducting this result, CEO considered the level of difficulties of what methods can be applied to the market directly and what methods can be produced the impact able economic benefit.

CEOs selected material reduction methods in 1st place because this method can make the largest profit against investment. The reason for this was changing product shapes, and product structures for assembly and disassembly would save production costs and create new opportunities for premium environmental products through the application of high-end alternative materials. Contrary to this, reduced

functionality has potential risks if the product does not show innovated functionality, instead of reduced functions to effectively appeal to consumers. Moreover, the reduced function method can achieve significant consumer demands e.g. extend battery lifespan and energy efficiency, however younger aged consumers emphasises new functionality this has a negative effect.

Task	2	What eco design method can appeal to consumers the most?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	6	2	5	2	7	8	4	1

Table 8.5 CEO's reply re what eco design method appeals to consumers the most?

This table demonstrated the rank of what eco design methods can be appealed to consumer effectively in CEO's perspective. As this table, higher ranks have been taken by scale of common fact between context of eco design method and mobile phone market trend and concern.

CEOs selected the energy saving method as the strongest appeal to consumers within exercised eco design methods because this method can cover the complexity of mobile phone functions and traditional markets concerned with power consumption problems at the same time. CEOs estimate that energy saving methods would have the effect of enhancing a company's environmental reputation and consumer demands are an economically based benefit.

In contrast, the reduced function method would be a better approach for investors however to use this method from a consumer perspective requires i) finding alternative materials with higher efficiency and eco-friendly value, moreover this alternative material has to reflect market demand. Often lightweight products or smaller products become regarded as a cheap product therefore applying this method would require a significant marketing approach and public relationship building.

Task	3	What eco design method can be difficult to undertake by current company situation? And why?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	6	6	4	1	2	1	4	8

Table 8.6 CEO's reply re what eco design method can be difficult to undertake in company currently? And why

This table shows ranks of difficulties to directly apply to the mobile phone development in eco design methods. That namely can be decided by level of current technologies company have and how distance between eco design context and market trend. In hence, to adopt the eco design method, the company essentially needs to understand the economic and technology circumstance.

CEOs assumed the most difficult eco design methods were upgradability and reduced material. The problems with the upgradability method is that mobile phone manufacturers have related component manufacturers (mostly small-medium sized companies) however, to achieve this method requires structural change to manufacturing and also each component importance would increase as much as current mobile phones (finished products) therefore, mobile phone companies have to produce most components in-house. The current mobile phone market is based on finished goods and manufacturers or product providers supply these to the mobile service providers and distributors. To apply this method, CEOs asserted that they i) need to modify entire supply chains, ii) require increasing component production lines and iii) establish solutions for surviving related companies.

The reduced function method could have face difficulties with recent consumer demands are very focused on functionality and high performance. As mobile phones become convergent with smart technologies these factors can be stronger, which decision maker. In contrast, energy saving method could be the highest rate or realization because mostly mobile phone manufactures have tried to improve power efficiency and moreover most of each mobile phone producer has identified technology. CEO also estimate current international eco regulations are focused on two different ways that i) reducing toxic materials and enhancing recycling percentage and ii) improving energy efficiency however energy problem would be accelerated and more segmented in the future.

Task	4	What eco design method can be the most related to current company environmental policy?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	3	5	1	5	5	1	4	1

Table 8.7 CEO's reply re what eco design method can be the best for current company environmental policies

CEOs answered that currently their eco policies focus on recycling and energy efficiency therefore energy saving and recycling methods can be the most appropriate, however reduced material is also intended in the near future to establish effective solutions to international environmental regulations. In the case of the recycling method, CEOs replied that most Korean mobile phone manufacturers have huge pressure on waste collection instructions, (CEOs expressed 'collection instruction and emphasis provider's responsibility rather than WEEE). Contrary to this, CEOs answered that anti-fashion, upgradability and reduced function methods could not find relationships with current company environmental policies, however through these interviews, CEOs will refer to these approaches; such as simplified production process and material reduction to help build new eco policies and apply them, this requires new certificates from the government and international organisations.

8.7.1.2 Eco design method in designer's perspective

Before starting the interviews, the author asked the designer for their opinion re the possibility and limitations of eco design.

The designer responded re limitations of eco or sustainable design has traditionally been accomplished in conceptual design. Designers asserted that eco design started from the purpose of enlightenment for environmental preservation through an implementing campaign and exhibitions raising awareness about environmental protection. However recent eco design has to have marketability and productivity, which follow industrial design principles rather than social production and cultural impact. Therefore the paradigm for eco design changed from emphasising creativity and the delivery message to balancing environmental demand and market trends. In summary, these eco design approaches may give interest to designers and create higher awareness.

Task	1	What eco design method can be the most related to current company design strategy?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	6	4	3	7	8	5	1	2

Table 8.8 designer's response re what eco design method can be most related to current company design strategies

Generally designer has been followed the company philosophy and design strategy for building design concept. This table shows the ranking of possibility to adopt the eco design method with considering current design direction and strategy.

Although mobile phone manufacturers use different design strategies, designers who participated in this interview stated that their design strategy focuses on mobile phone functions, which are becoming complex, mobile phone design has to reflect usability, based on user's intuitions and experience to maximise usage functionality. The durability method recently became more important as mobile phone prices increased. However, the designer stated that upgradability and reduced function methods have a gap with current design approaches and DfD is also difficult to realise without solutions for reinforcing strength. Moreover some particular mobile phones follow strong security regulations for assembly and disassembly therefore although DfD could be an effective solution to increase rates of recycling, applying this method needs more consideration for protecting core technologies, which are on-board within high-tech mobile phones.

Task	2	What eco design method can be realized by current situation (technology and company policy)?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	2	5	1	6	8	7	3	3

Table 8.9 designer's response re what eco design method can be realised through current technology policies

This table illustrated the ranks of possibility to realize with considering the current technologies; company has and also thinks about relationship between company philosophy and each eco design method.

Participating designers asserted that global markets, developed technologies and markets and continuously require improved design for increasing rates of recycling

or recyclable products. Most mobile phone manufacturing companies aimed to achieve 'cradle to grave' through enhancing rates of recycling which could create commercialised recyclable mobile phones. Furthermore, recycling and DfD methods could be the next step for eco design direction.

Task	3	What eco design method can be the most effective to the market?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	5	1	6	1	8	7	4	1

Table 8.10 designer's response re what eco design method can be the most effective in the market

Designers stated that the most effective eco design method on the market was anti-fashion, upgradability and the energy saving methods. Designers asserted that anti-fashion, despite depending on the design quality and marketing strategy, achieved valuable innovative design and technology and would appeal to consumers the most. To explain this, designer's exemplified Apple i-phone as a current iconic product in the smart phone area, this mobile phone achieved a balance between innovative technologies and design quality but most significantly it created new markets and mobile phone categories and through this gave longer product lifespans through functional and emotional satisfaction.

The energy saving method can be an attractive approach to solving battery life problems, which most current mobile phones have. From a designer's perspective, approaches of upgradability or function improvement, the research showed that previous CEO's answers required building new product component markets and compromising between manufacturers.

Task	4	What eco design method can be the most effective to the environment?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	5	5	1	8	8	7	4	1

Table 8.11 Designer's response re what eco design method can be most effective on the environment

Although ranking the effectiveness of eco design methods through environmental issues needs the same conditions as quantitative evaluations. If all products apply

the same conditions then designers select recycling and energy saving methods as the most appropriate for environmental issues. The reasons for designers' choice is for on-board innovative environmental technologies and improved supporting systems such as collection and sorting systems for recycling, which could be more effective rather than changing the shape or improving usability from an environmental perspective. This means that in the case of the energy saving method, which can sharply decrease power consumption through alternative energy, unlimited energy e.g. solar power, innovated battery technologies and direct charging technologies.

However, the recycling method requires new recycling systems for the particular product, designers asserted that mobile phones and refrigerators need different collection and sorting systems for more effective recycling and without improvement of the recycling system, eco design methods for recycling could not improve.

8.7.2 Eco design method from a marketer's perspective

To understand the marketers' perspective, the author asked general questions re eco design before starting the interviews. Marketers asserted that eco design and eco product developments have become core factors in the markets globally and this important fact means eco has been extended from 'for the environment' to 'for the environment and humans'. This does not mean that the purpose of eco design is for humans through environmental preservation, which is a very traditional definition. Current eco design concepts reflect social and market trends and can be defined as protecting the environment and humans at the same time through environmental consideration e.g. developing non-toxic materials and less pollutant emissions and various social awareness strategies, such as LoHAS and Well-being are social booming in 2007.

Marketers asserted that despite increasing importance of the relationship between environmental issues and international environmental regulations, current eco standards did not impact market success because most global mobile phone manufacturers use less toxic materials, which can alternate restricted materials and create better environmental production processes and have a correspondence

manual for future environmental regulations. Moreover, most companies have not used environmentally friendly information with marketing tools because recent mobile phones, particularly competitive models fulfilled most eco standards and also have innovative environmental technologies applying eco-friendly materials, compared with current mobile phones and products made on or before 2000. That means most current mobile phones could be developed through environmental considerations and many producers already achieve innovative environmental technology success.

Therefore applying eco design to mobile phones requires identified environmental achievement e.g. at Samsung Blue Earth phone has applied environmentally friendly ideas such as using recycled paper for the multi-functional package, this package also uses photo flame by transform. This approach appeals to consumers by using attractive environmentally friendly ideas.

Task	1	What eco design method can be the most effective in the markets in long-termly?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	3	1	1	5	7	6	8	3

Table 8.12 Marketer's response re what eco design method can be the most effective in the markets in the long term

Marketer had the negative opinion about eco design and eco design method traditionally because this area had not shown the obvious market impacts traditionally however this mind has been changed as increasing the people's concerns about environmental friendly issues and marketers also recognized how important and effective approach to manage the company reputation via establishing social and environmental benefit both.

Marketers selected anti-fashion and recycling methods as most using effective methods in markets in the long term.

With the anti-fashion method, the marketing department has the most significant role to achieve this method, which requires significant marketing strategies and strategic milestone for the marketing investment. This requires maintaining public

relationships and supporting services to extend product lifespan. Therefore to complete this method, it needs systematic division of roles, meaning each department such as R and D, design, engineering and marketing have to work flexibly and responsibly. The recycling method requires a large investment to establish facilities but the largest investment or difficulty is to attract positive consumers to participate. Marketers still consider recycling could provide opportunities by opening new environmentally friendly markets as these consumers' participation also decides success or failure from a marketing perspective. Marketing is based on sales and this fact will be decided by consumer concerns.

Marketers asserted that if recycling methods succeed in the market then this will achieve i) satisfaction re most international environmental regulations being enforced, ii) the product using recycling methods can give environmentally positive images to consumers and be better placed in the environmental markets and iii) this can be a stimulant to establish environmentally friendly markets.

Task	2	What eco design method can be the most effective in the markets in short-termly?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	6	4	5	4	8	7	1	1

Table 8.13 Marketer's response re what eco design method can be the most effective in the markets in the short term

Table 8.13 demonstrated the answers from marketers that what eco design methods can be shown in short termly and mostly the marketers' opinions that although the most of eco product could not produce the benefit in short termly however if some of context in eco design methods may related to arising issues such as energy and battery then this eco product can be make both benefit immediately.

Marketers selected durability and energy saving methods to be the most effective methods in the short-term. Users have demanded better solutions for the battery problems and product strength since mobile phone price rises. Marketers also asserted if the mobile phone embedded waterproof technologies or innovatively increased the reinforcement of mobile phones, then this product may satisfy consumer concerns. Marketers also estimated many mobile phones have replaced

refurbished phones, as high cost to repair or dispose through users' carelessness or bad manufacture of the product, however upgradability, which marketers selected as 3rd ranked could be the appropriate solution to decrease waste mobile phones through changeable or modular components.

Task	3	What eco design method has it got the highest possibility of realization in current states?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	4	6	3	7	6	5	2	1

Table 8.14 Marketer's response re what eco design method has it got the highest possibility of realisation in current states

Marketers asserted that to achieve eco design or to adopt eco design methods, the product has to have friendship, which can attract to consumers by authentic product values and also this requires the obvious expectable benefit in business perspective.

Marketers selected the energy saving method to be the most appropriate eco design method for realisation in considering current company capability and directions of company policies. Similarly to CEOs answers, marketers asserted that most mobile phone manufacturers have considered energy efficiency as their highest priority. Reduced material, which is ranked 5th within 8 design methods, can be effective to produce popular products or cheaper products. However the problem is that saving materials requires higher technologies to cover functional losses and needs more expensive and multi-functional material, therefore this method could be difficult to realise at this time. Marketers commented that DfD has been tried in many product ranges especially home appliances to reduce production costs and for implementing after service care, however most mobile phones are still very difficult to disassemble and because this product uses secure high technologies and contains sensitive personal data. The marketers asserted that DfD can be an effective solution for increasing recycling rates but mobile phones have the highest level of security system within the entire product groups.

Task	4	What eco design method can be the most relationship with current company marketing strategy?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	7	6	1	5	8	4	3	1

Table 8.15 Marketer's response re what eco design method can have the best relationship with current company marketing strategy

Marketers answered that energy saving and recycling methods can follow the strategies. Moreover, the reduced material method could also correspond with company policy and marketing directions focus on saving materials and protecting natural resources. They illustrated recent mobile phone manufacturer policies and companies have pinpointed two different market strategies; premium and popular markets. The company also has product development strategies for emerging markets such as India and Brazil and third world countries therefore various eco design methods, especially reduced materials and upgradability will be more significant solutions.

8.7.3 Eco design method from engineers perspectives

Recent mobile phone technology developments could change the spectrum of global electronic markets. To illustrate this aspect engineer's exemplified current rivalry between Apple and Samsung as changing shapes and functions of mobile phones as well as the paradigm of electronic products, therefore successful mobile phone developments could decide company survival. Innovation technologies for mobile phones have not only become significant factors to markets but also the major decision making factors for company survival.

Engineers asserted that Korean mobile phone manufacturers have enhanced functional achievements for productivity and product efficiency rather than aesthetic innovations. Most achievements are for time and functions, which have high priority and through this have helped to lead the Korean mobile phone industries' success e.g. Korea is the first user of DMB (Digital Mobile Broadcasting) by CDMA (Code Division Multiple Access) technology. However, engineers asserted that recent definitions of technology values have been required which reflect environmentally

friendly issues from markets and consumers, who demanded that environmentally friendly factors connected to functional benefits are more segmented. Most Korean mobile phone manufacturers established task force teams for in-house development, however since initially developing mobile phones in Korea Company strategies have focused on innovating functional technologies therefore many companies have faced difficulty in changing their development strategies. As previously discussed, developing eco design products has difficulty appealing to consumers rather than with functional achievements and most recently eco design technologies improved with non-recognition of user e.g. material reduction and DfD approaches focus on production and disposal processes therefore these methods are dependent on the manufacturers' social responsibility. In conclusion engineers considered that the right approaches for applying eco design methods requires cooperation with other departments such as marketing or design to build strategies for effectively appealing through public relationships and creating new designs.

Task	1	What eco design method can be realized by current situation (technology and R and D directions)?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	3	8	1	7	6	4	4	1

Table 8.16 Engineer's response re what eco design method can be realised at present (technology and R and D directions)

Engineers stated that with current eco policies, energy saving and recycling methods could be used, (similar to marketers' answers). The engineering department has developed their own quantitative standards and manuals to develop batteries and charging technology to reduce power consumption for maximising usability. According to this, the company implemented manuals for reducing material consumption however most methods applied to white home appliances such as refrigerators and digital television because mobile phones are much smaller than any other electronic products and with increasing mobile phone prices, consumers expect high-end materials.

Task	2	What eco design method can be difficult to realize currently?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	8	7	6	1	2	3	4	4

Table 8.17 Engineer's response re what eco design method can be difficult to realise currently

Engineers stated that eco design methods can be realised through current technologies, however the problems of applying these methods have not negative economic benefits within different stages of the product lifecycle therefore applying these methods to product development needs economic verification, environmental and social value from a company perspective. For example, in the case of upgradability, engineers explained that some previous mobile phones had physically upgradable structures and most smart phones can be updated with software (engineers exemplified a Samsung mobile phone, Galaxy which has an additional slot to upgrade hard drive capacity and Sony mobile phones also have an external slot to extend its capacity). Engineers also asserted to achieve reduced function, it has to develop mobile phone different usage methods by multi sensorial approaches to maximise usability of efficiency and lead to power consumption reductions. Power consumption has been a key issues since smart phone development because it increased the size of display and users have depended more on the communication device than previously. In summary engineers asserted that undertaking eco design methods needs consideration for the economic benefit within product lifetime and the most significant factor is realising eco design product is to quantitatively diagnose consumer usage behaviour giving functional priority.

Task	3	What eco design method can be the effective against RandD investments?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	5	8	6	3	7	3	1	1

Table 8.18 Engineer's response re what eco design method can be effective against R and D investment

Answer of engineer about selecting the most effective eco design method against different level of R and D investment needs to be based on current company's concern, market issues and consumer's requirements.

With respect to R and D investment efficiency, engineers selected energy saving and durability methods, which was similar to the marketers' selection re short-term profits because those methods focus on current markets and consumer demands for extending battery life and reinforcing product housing. Most engineering department and R and D areas implemented previous research and development for this compared to other eco design areas. Engineers estimated the upgradability method could be the most powerful method because if components could be manufactured as modular products then it could sharply improve the quality of after-service and develop innovative functions such as wireless battery charging technologies.

Task	4	What eco design method can be the most appropriate in environmental friendly aspect?						
Eco design methods	DfD	Anti-fashion	Recycling	Upgradability	Reduced functions	Reduced materials	Durability	Energy saving
Ranking	5	8	1	6	7	3	3	1

Table 8.19 Engineer's response re what eco design method can be the most appropriate in environmentally friendly standpoint

Engineers chose energy saving and recycling methods, similar answer to marketers' answer for selecting eco design to correspond to their current marketing strategy. Engineers asserted that current recycling technologies can rapidly increase recycling rates for mobile phones however, implementing the recycling approach, applying recyclable materials and building recycling systems require large economic investment. Most manufacturing companies have been more focused on energy saving, which reflects consumer demands rather than recycling approaches. Engineers differing opinion to other experts when implementing the reduced material method, when completion of quantitative evaluation re amounts of material reductions they found alternative materials with less toxicity and reduced environmental impact than this method could produce higher rates of realisation.

8.8 Findings of decision makers through expert interviews

This section will establish project decision makers, implementing department and project managers for eco design through expert discussions. This will estimate how the eco design methods will be undertaken in different areas, will provide

background data for evaluating business importance and relationships between different areas and find appropriateness for eco design methods from a business perspective (see chapter 8).

	Project Manager	Department of project implementation	Project decision maker
DfD	Head of R&D / Head of department of technooogy	R&D / Engineering	CEO / CFO / CTO
Anti-fashion	Head of R&D / Head of Marketing / Head of Sales	R&D / Marketing	CEO / CFO / CTO / CMO
Reduced function	Head of R&D / Head of Design	R&D / Engineering / Design	CEO / CFO / CDO
Reduced material	Head of R&D / Head of Design	R&D / Engineering / Design	CEO / CFO / CDO / CTO
Recycling	Head of R&D / Head of Design Head of Marketing	R&D / Engineering / Design / Marketing	CEO / CFO / CDO / CTO / CMO
Energy saving	Head of R&D / Head of Design Head of Marketing	R&D / Engineering / Design / Marketing	CEO / CFO / CDO / CMO / CTO
Durability	Head of R&D / Head of Design	R&D / Engineering / Design	CEO / CFO / CDO / CTO
Upgradability	Head of R&D / Head of Design Head of Marketing	R&D / Engineering / Design / Marketing	CEO / CFO / CDO / CMO / CTO

Figure 8.22 Finding decision makers, implementation departments and project managers

* Acronyms: CEO – Chief Executive Officer / CFO – Chief Financial Officer / CDO – Chief Design Officer / CMO – Chief Marketing Officer / CTO – Chief Technology Officer

In figure 8.22, energy saving and recycling methods could involve most departments and recently more than 3 departments collaborate in developing new energy saving technologies, across different departments and monitoring the effect.

According to figure 8.22, the importance of design and marketing departments have increased however the R and D department still has the target role of mobile phone development. Engineers illustrated the current methods of project implementation that R and D departments undertake and are responsible for long-term projects, which require developing technologies or company milestone strategies, other departments such as design and marketing support them. Eco design projects normally accomplish their goals in the long term and use more investment hence, this needs the CFO's decision, who manages the financial functions for the project, involving higher level persons such as chief managers (CTO, CDO and CMO) as the decision makers.

Eco product developments require very specific knowledge based expertise such as eco evaluations and eco technologies. It is difficult to achieve entire related technologies and systems development which do not have economic benefit than compared to collaborating with various outsourcing companies and eco product experts.

8.9 Summary

According to the expert interviews, eco product developments potentially have higher economic risks and potential risk elements over general product development. Eco products have smaller economic benefit compared to high investment products. More than three or four different departments collaborate for developing eco product or eco materials because current eco products require knowledge based expertise which influence wide range market areas, therefore this often requires outsourcing or involving experts. Consequently this could show evidence re a shifting paradigm for eco products which has become more segmented and detailed than previous eco products or eco designs.

Below is a list showing the results from the expert interviews.

- i) Developing eco products require higher investments therefore CFOs need to be the decision maker and agree to execute budgets.

ii) Energy saving and recycling methods are the most compatible to current company eco policies and similar approaches to eco design methods have been applied to recent eco product developments.

iii) In the case of the energy saving method which is most related to current markets' and consumers' demands, marketers asserted this method can impact the markets directly.

iv) Increases in consumer concerns re eco product developments, have forced companies to assess essential factors in eco product development, however with only limited implementation undertaken in energy saving or developing alternative materials.

v) There was much focus on balancing considerations between environmental and economic values and without economic benefits, the companies would not implement this, which makes it difficult to realise. This means that current eco design issues follow fundamental markets and industrial design principles.

Summary of chapter 8

- Found the different issues about how to recognise eco design in different field of industry
- Developing environmental products require longer and bigger investments than normal projects. This requires a strategic level of management to be involved, in the decision making and as well as collaboration by multiple departments
- Energy saving and durability methods as have developed in mobile phone manufacturing, have traditionally been the most appropriate methods, because these reflected the mobile phone users' demands
- CEO and marketer selected the similar eco design methods in question about realisation and designer and engineer have answered the similar.

- These reasons are i) designer and engineer understand the physical product spec and technologies however ii) in case of marketer and CEO require the economic benefit in short & long termly

Chapter 9. Finding

Precis of chapter 9

- Determine how and what types of effect addressing eco design methods in terms of both environmental and business standards by cross comparing analysis
- Finding the essential factors that increase rates adoption of eco design methods in product development through a process of cross comparing
- Determine types of market requirements (International environmental regulations) to identify the effectiveness of eco design methods
- Exploring the appropriate eco design methods for adoption by the mobile phone manufactures versus consumer's perspective

9.1 Structure of finding method

This chapter uses Eco Compass to represent the LCA results. Through this process, the results will show differing issues from each eco design method within Eco Compass. In applying this representative tool, it adds importance to the LCA results by ranking market impact, major international environmental regulation influences (section 9.2.2) whilst also reflecting the importance from the different sectors within mobile phone manufacturing companies.

These results will provide the appropriateness for eco design methods by raking the environmental benefit against the investment through cross comparison of the results.

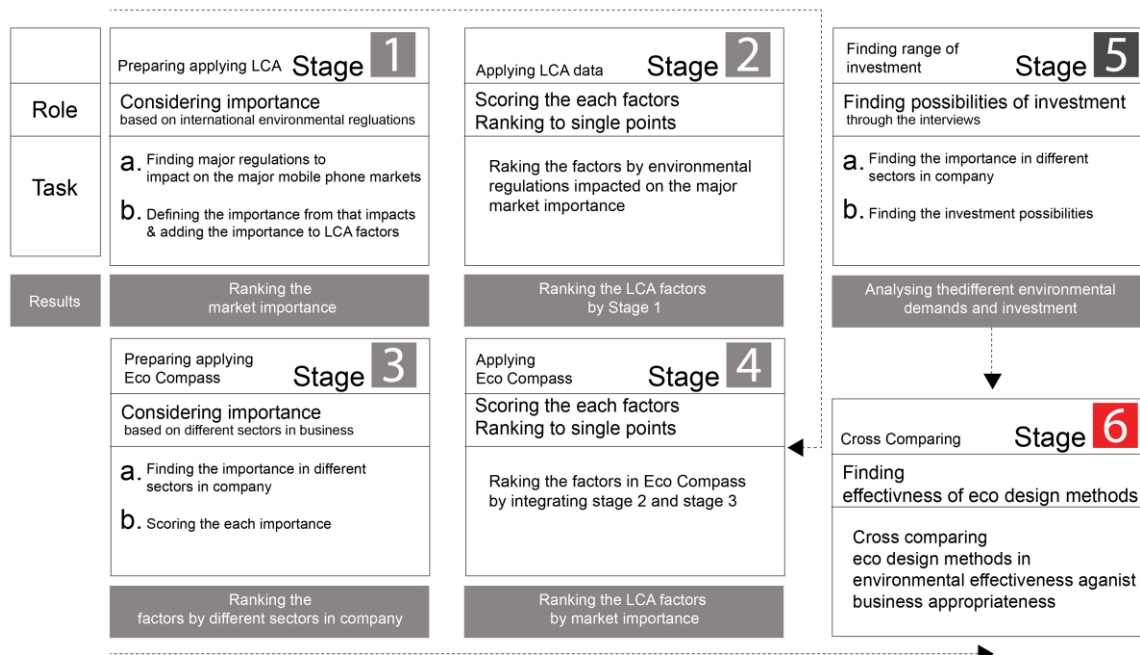


Figure 9.1 Structure of finding research results

Figure 9.1 shows the result structure and consists of six stages for establishing standards and analysis of the data. Each stage of the findings has been given importance based on the exercises and evaluations previously undertaken and through the implementation of cross comparison between environmental and business aspects to understand the most appropriate eco method to use.

The results were generated based on giving different rates of importance to different factors within LCA and Eco Compass. To establish these importance ratings, the researcher undertook interviews with CEOs, marketers, designers and engineers currently working in the Korean mobile phone manufacturing industry. These interviews provided the answers for various significant factors that ‘most necessitate eco design factors currently for the company’ and ‘highlight different factors between environmental and business demand’. These answers present the purpose for undertaking eco design and the ecological capabilities in business.

Through the connection of the considerations for international environmental regulations in LCA and applying the importance values into Eco Compass through these interviews, the research will implement cross comparison (section 9.3).

The cross comparisons will show;

- i) Which eco design methods are most effective for differing sectors of the organisation?
- ii) What are the different issues looking at in different roles within the company?
- iii) What eco design methods are the most cost effective against investment levels?

Through analysis, the author will deduce the results through cross comparison between environmental aspects and importance values (levels) for the different departments, to help generate the research results needed and reliable background research for the importance of environmental and business perspectives. LCA provided environmental effectiveness, which shows different environmental impact through quantitative approaches and UL110, which was undertaken for finding the importance for environmental legislation and importance of business aspects produced by the US independent safety science company.

9.2 Standards for importance rating

9.2.1 Structure for finding appropriate approach

Previous research defining differentiation for importance within business and the environment was applied using UL110, which studied environmental importance within the mobile phone industry; this report was published in the US in 2013. To understand the relationship between each business phase and major environmental issues, the author made connections to Eco compass and UL110. Through this approach this research presents i) different importance rates within the mobile phone industry for environmentally friendly areas, ii) deductions for different estimated business achievement through features of eco design methods and iii) estimations of the range adoptions for eco design methods by comparisons of environmental achievement and business benefit.

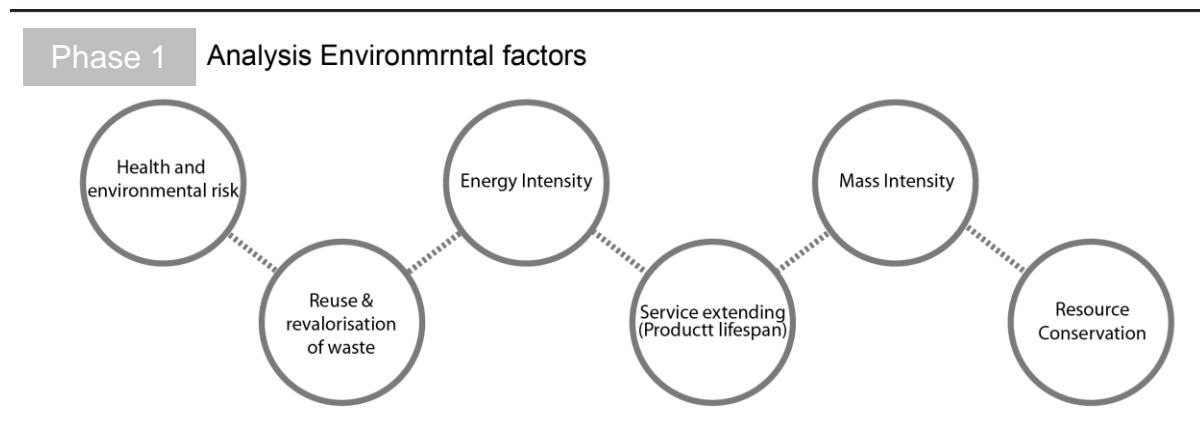


Figure 9.2 First stage of findings (generating and collecting data)

These elements are based on Eco compass, which is a representative method for this research. The environmental factors were developed by the analysis framework in chapter 5 to reflect the values for environmental perspectives and the features of each eco design method, adapted for this research. The results obtained through the use of the Eco compass method will be shown in section 9.3.

According to figure 9.2, LCA analysis provides the fundamental data for the entire environmental factors except 'service extending (product lifespan)', therefore expert interviews were undertaken, surveys regarding the Korean mobile service contract were completed and relationship research between product lifespan and the Korean mobile phone service providers to find the issues within this area. However to understand the environmental issues from the service perspective, which reflects market trends and consumer' requirements, it needs to implement the survey to broader targets in other regions and cultures and moreover there are limits for this research level such as; the conditions and cultural differentiations between manufacturers and service providers making more clear the current limitations for implementing environmental business activities.

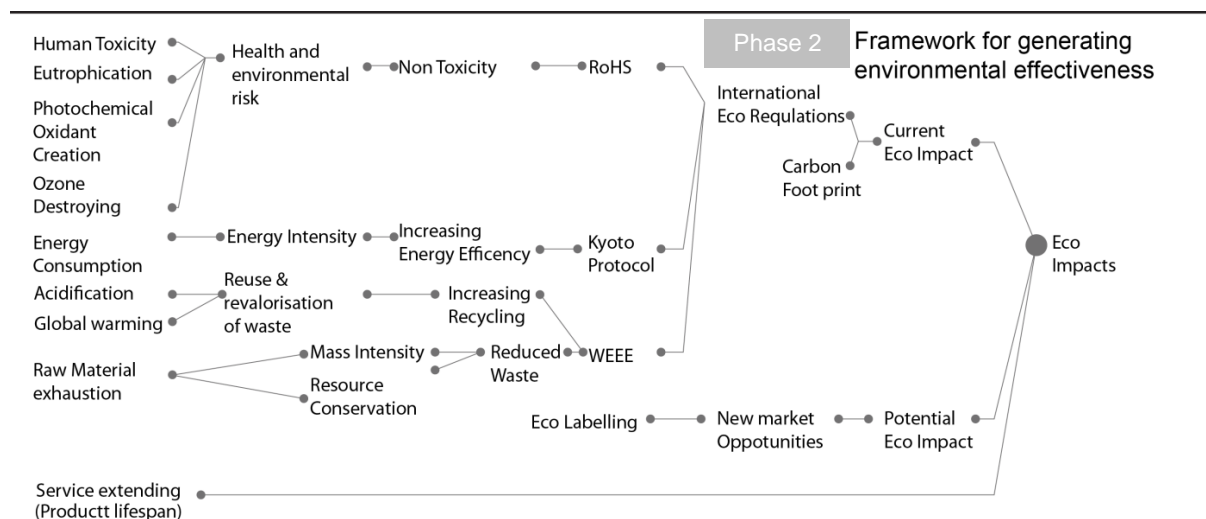


Figure 9.3 Second stage of findings (establish the framework for generating environmental effectiveness through different aspects of major international environmental legislation)

This figure illustrates that how to generate the data for the effectiveness of eco design methods through hierarchical chains. Referring to this analysis, environmental impacts are based on the Eco compass and have also impacted the mobile phone industries connected to the three major international environmental regulations: RoHS, WEEE and the Kyoto protocol. These regulations have been enforced for specific areas for example, the purpose of RoHS focuses on restricting toxic materials during the product lifespan, therefore the related area with Eco compass will be Health and the environmental risk. This category can be connected to Human toxicity, Eutrophication, Photochemical, Oxidant creation and Ozone destruction in LCA analysis. These factors consider evaluating sustainable environmental and human impact through the use of toxic materials and products, which contain harmful materials. The purpose of the Kyoto protocol is to reduce the amount of CO₂. The distinguished feature of this legislation is to implement the CO₂ emission trading system, which recognises the environmental rights as the means of trading initially. The Kyoto protocol manages carbon footprints, controlling the emission materials and this controls a wide range of targets such as products, users and the environment. In this research, the Kyoto protocol can be connected to Energy intensity in Eco compass analysis, although as a research limitation, this research only implements usage levels for energy consumption through LCA

however, to discover more detailed data this needs to calculate the entire amounts of energy consumption from production through to recycling.

The fundamental aim of WEEE is to concentrate on environmental responsibility from users and consumers to providers and manufacturers through enforcing the extended producer responsibility (EPR), which means collecting and disposing of waste electrical and electronic products by the producers. Therefore, this regulation has achieved an increase in the rates of recycling and waste material reductions. Within this analysis, WEEE can be connected with Reuse and revalorization of waste, mass intensity and Resource conservation. These are all categories focused on reusing material waste and recyclable materials; in this research the author analyses environmental impact as differing amounts and types of used material through each eco design method.

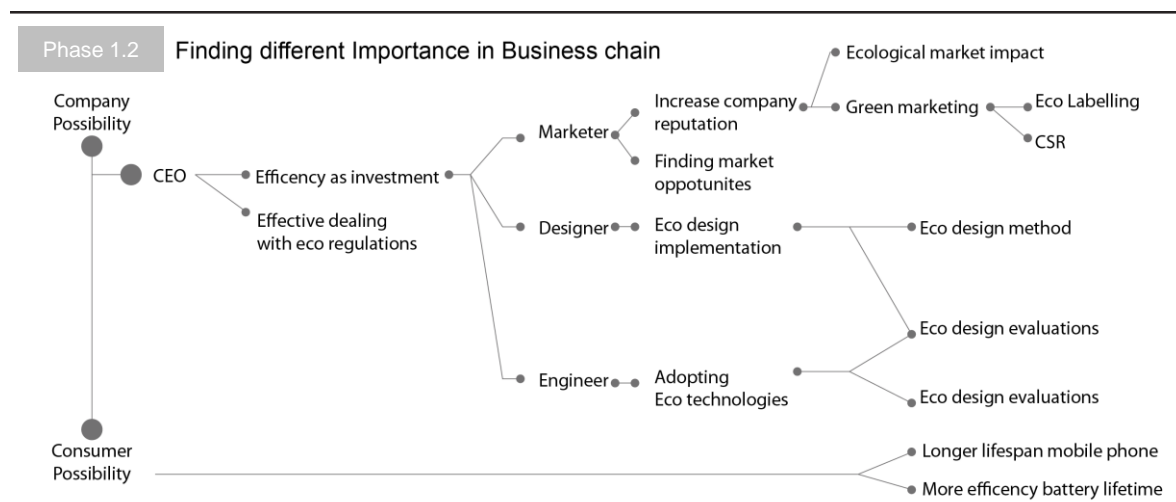


Figure 9.4 Third stage of findings (establishing the framework for generating business potential through different business issues and project drivers)

Figure 9.4 shows the hierarchy chain for developing environmentally friendly products. These elements can be divided into provider and consumer' demands and the aim of the business perspective is to focus on the potential benefits; generating economic benefits, increasing social reputation and enhancing environmental responsibility. Consumer' perspectives mostly concentrate on direct functional and economic benefits.

According to this figure, despite decision-making levels of CEOs, marketers, designers and engineers influenced decisions and stimulated the development of environmentally friendly products by understanding markets demand and consumer trends. Furthermore, each department in the company has a different strategy for dealing with environmental issues so these factors will provide distinguished requirements, policies through standards.

Although this research approach was undertaken, there have been a limited number of previous studies. This is mostly economic benefit without enhancing social awareness for finding the effectiveness of business, however this research presents i) the initial approach for comparing economic and environmental achievement through structural frameworks and environmental evaluating methods, ii) reflection of the future environmental industry opportunities, which apply environmental enterprise and iii) estimating business possibilities compared to environmental achievements.

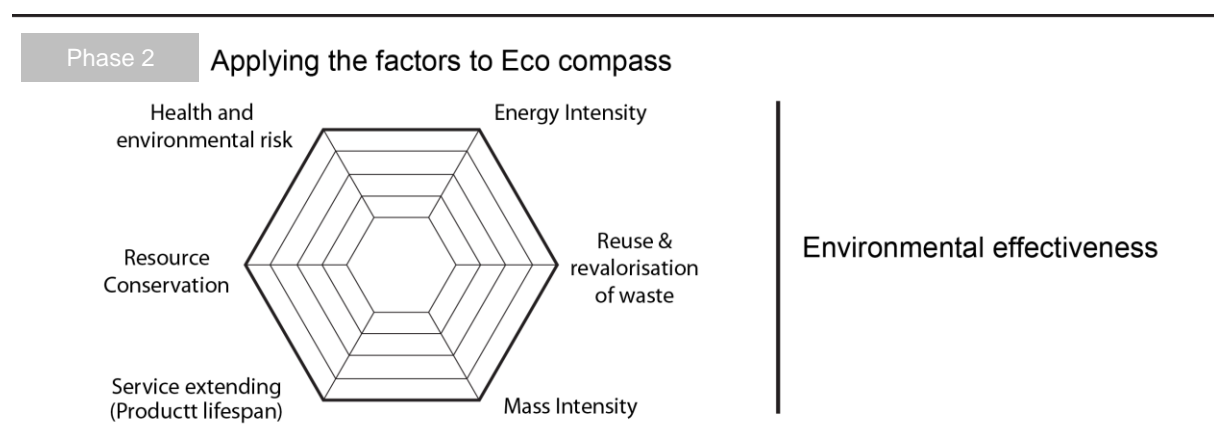


Figure 9.5 Fourth stage of findings (applying Eco compass for representing environmental impacts for cross comparison)

To collect the data, the author found, calculated and estimated previous inventory data based on current mobile phones for the LCA in the early stages of this research (see appendix 4). To accurately analyse for LCA requires inventory data from existing products, however for the purpose of this research in finding the effectiveness of eco design methods, inventory data for this research is based on conceptual design results, which were undertaken through qualitative pilot study guidelines (chapter 5), the LCA results are in appendix 6.

The LCA data will provide comparable values for different environmental impacts (see chapter 7 and appendix 6), cross comparison for each method and will apply the Eco compass environmental representative method.

Phase 3		Range of Investment				
	Existing Capability	Extending Marketing	Improve Process	New process	Infrastructure	New R&D programm
(Million)£	1	3	7	20	55	150

Figure 9.6 Fifth stage of findings (Steps costs for different investment phrase)

Step costs are based on the following increments; existing capability; extensive marketing; improved process; new process; investment in infrastructure (e.g. return-to base collection and recycling facilities); new R&D capability and the extent to which the success of each eco design approach is reliant on this.

9.2.2 Structure of approaches for findings

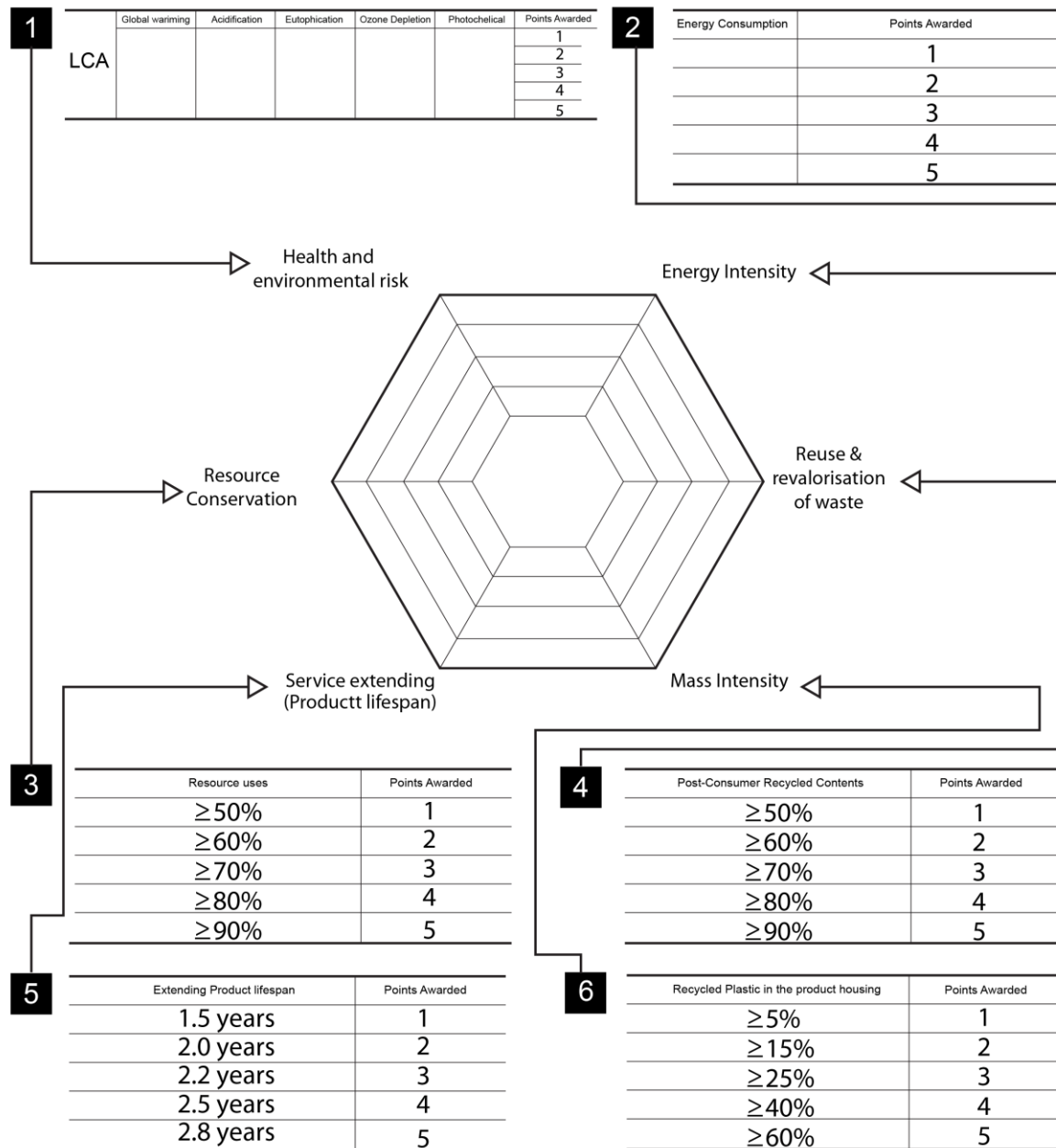


Figure 9.7 Reflecting business for different importance to Eco compass

This figure illustrates ways of applying research data through LCA, interviews and surveys within Eco compass. To produce the results, UL110 provided the business importance and according to the results, categories for Eco compass applied

different rates of importance which were also considered with a range of investments, mentioned in phase 3 to generate research results, which suggests the effectiveness and possibility of each eco design method from a business perspective.

Within health and the environment, business importance is deducted as well as environmental impact and human toxicities from LCA. It will estimate the various environmental impacts during the mobile phone lifespan and suggest the most effective method to deal with these facts through this research implementation. In the case of the Energy intensity, this will present the effectiveness of applying the method against investments and particularly, as previously mentioned, this area may become not only a significant field for environmental preservation but also for commercial enterprise.

Resource conservation may only be thought of for saving money through the reduction of material consumption from a manufacturers' perspective however, another purpose of this method considers new innovated structures and systems for more effective material use to preserve natural resources and restrict wasting the earth's resources, therefore to produce the data the author calculated total material consumption by LCA combining business importance.

All design results were controlled with the same conditions applied to the same specification except the reduced material method. The author and the participants produced design results, which did not show huge differentiation in physical product specification. The reuse and revalorisation could be connected to post-consumer recycled contents because this factor means that the differentiations of users' concerns regarding recycling and shifting recycling rates are carried out through these users concerns.

To produce the results for extending the product lifespan, the author found the average mobile phone lifespan according to consumer interviews and also surveys of average mobile phone service contracts with the Korean mobile phone service providers. Through this implementation, the author understood current mobile phone lifespans and also found major reasons for changing mobile phones and key decision making factors for purchasing new mobile phones. These issues provided

background information to estimate the range of service extensions for use with Eco compass. The mass intensity will show the efficiency of material use and rates of recycling materials.

This research will suggest ranking eco design methods for quantitative material efficiency and estimate potential opportunities through LCA.

9.3 Different international environmental regulations impacting the Korean mobile phone industry (major markets)

Aligning eco-design strategies to consumer lifestyles is only one approach. There are clear distinctions between optimising environmental impact, appealing to consumer's 'green' consciousness and regulatory compliance specifics and enabling (continued) access to regional markets.

It is possible to measure eco-benefit in absolute terms. Whilst this is useful, there is perhaps a greater imperative for a manufacturer to measure this in terms of eco-conformance and by region, enabling entry to key export markets.

Considering each of the major mobile phone exports destinations, the US is currently the largest client (with sales of \$4.2 billion per annum). China and Hong Kong are ranked 2nd and 3rd (with \$1.2bn respectively), India ranked 4th (\$0.7bn), East Asian countries (Singapore and Taiwan) ranked joint 5rd (\$0.4bn and \$0.3bn respectively) and the UK, France and Germany at 6th-8th (collectively \$1bn) (KOTRA; Korea Trade Investment Promotion Agency, 2007 Global Mobile Phone Market Estimations, KOTRA, Korea, 2007)

When analysing each market by regulation, figure 9.8 illustrates those regions covered by each protocol:

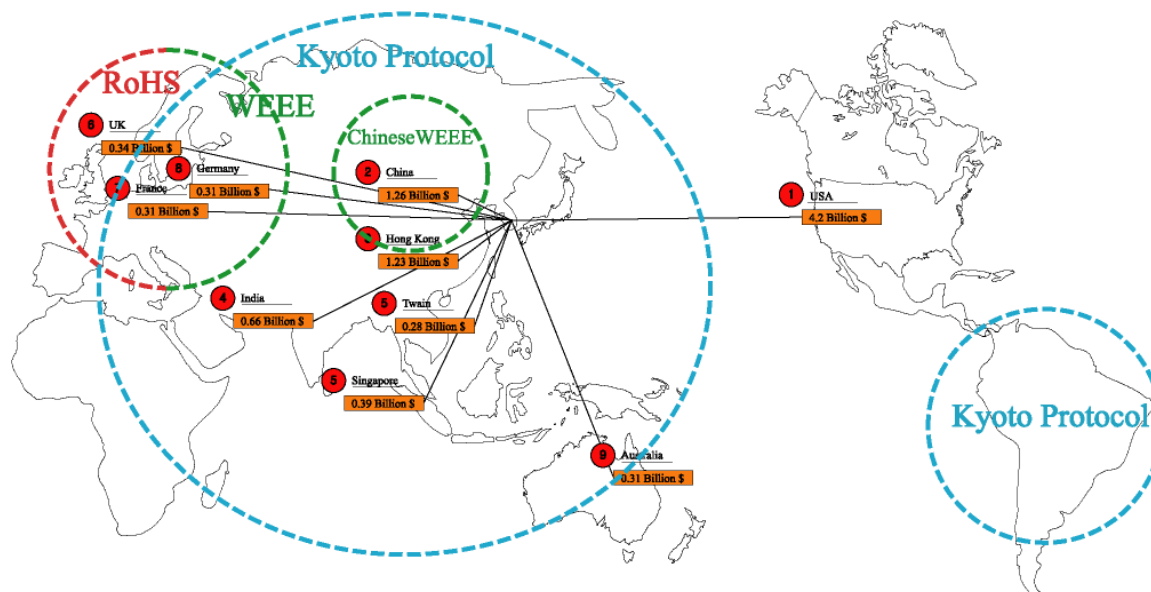


Figure 9.8 Ranking of Korean trading countries and ranges of eco regulations

Each environmental protocol can be mapped against the Eco-Compass to determine the most appropriate eco-tools for particular markets (see Table 9.1 to 9.3 and Figure 9.8) (KOTRA; ; Korea Trade Investment Promotion Agency, Report of the way to dealing with the international eco regulations-by centering on trading with China-, KOTRA, Korea, 2007).

The lists below show the rank of the highest impact on Korean trade by relationship between the global eco regulations and Eco-compass analysis. This analysis is based on the KOTRA data, which provided lists of top global traders and global eco standards. To understand what different aspect and contexts have in international environmental regulations, the researcher evaluated to red marks on significant issues in major legislations.

Ranking	Factors	Importance	Comment
1	Reuse and revalorization of wastes		Aim of WEEE is reduction of industrial wastes and increase recycling percent.
2	Health and environmental risk		
3	Mass Intensity		
4	Extending service and function		
5	Energy Intensity		
6	Scarce of Depleting resource		

Table 9.1 WEEE regulation ranking (by significance)

Ranking	Factors	Importance	Comment
1	Health and environmental risk		reduction of toxic industrial material
2	Extending service and function		
3	Reuse and revalorization of wastes		
4	Mass Intensity		
5	Energy Intensity		
6	Scarce of Depleting resource		

Table 9.2 RoHS regulation ranking (by significance)

Ranking	Factors	Importance	Comment
1	Energy Intensity		CO2 emission trading
2	Extending service and function		
3	Reuse and revalorization of wastes		
4	Mass Intensity		
5	Health and environmental risk		
6	Scarce of Depleting resource		

Table 9.3 Kyoto regulation ranking (by significance)

Evaluations of the tables indicate:

- Re-use/revalorisation of waste; health and environmental risk (waste toxicity); and mass intensity are the most critical strategies in the WEEE Chinese, Asian and European markets (50%)
- Energy intensity is key in all Kyoto regions, with the exception of the US (50%) who have not subscribed to this protocol
- Service extension is also significant in the European regions (12%)
- The US market remains unregulated (50%), and as such is dependent solely on the environmental conscience of the US consumer, (although recent reports indicate that Congress may pass a cap on the country's emissions of greenhouse gases in the near future (Korean Development Institute, 2009)).

There is some overlap/duplication in the various protocols. Broadly speaking:

- RoHS covers production and the use of toxic materials
- Kyoto protocol covers energy generation, and hence usage
- WEEE covers disposal and waste, converging with RoHS re valorisation, health/environmental risk and service extension

9.4 Deducted results for environmental effectiveness applied in a business perspective

This section presents the effectiveness of eco design methods through reflecting different business aspects in Eco compass. To deduct the LCA results in Eco compass the author has undertaken and found the quantitative importance from the confidence public research expertise company in US is called UL110. Referring to figure 9.9, each factor in Eco compass demonstrated the different aspects of LCA and showed comparable data such as looking at the Energy saving method and Durability method can be distinguished at energy intensity and mass intensity by context and aim of each method.

These Eco compass methodology can be demonstrated and decoded LCA results by more visually and transformed more understandable for non-ecologist and environmental specialist such as industrial designer.

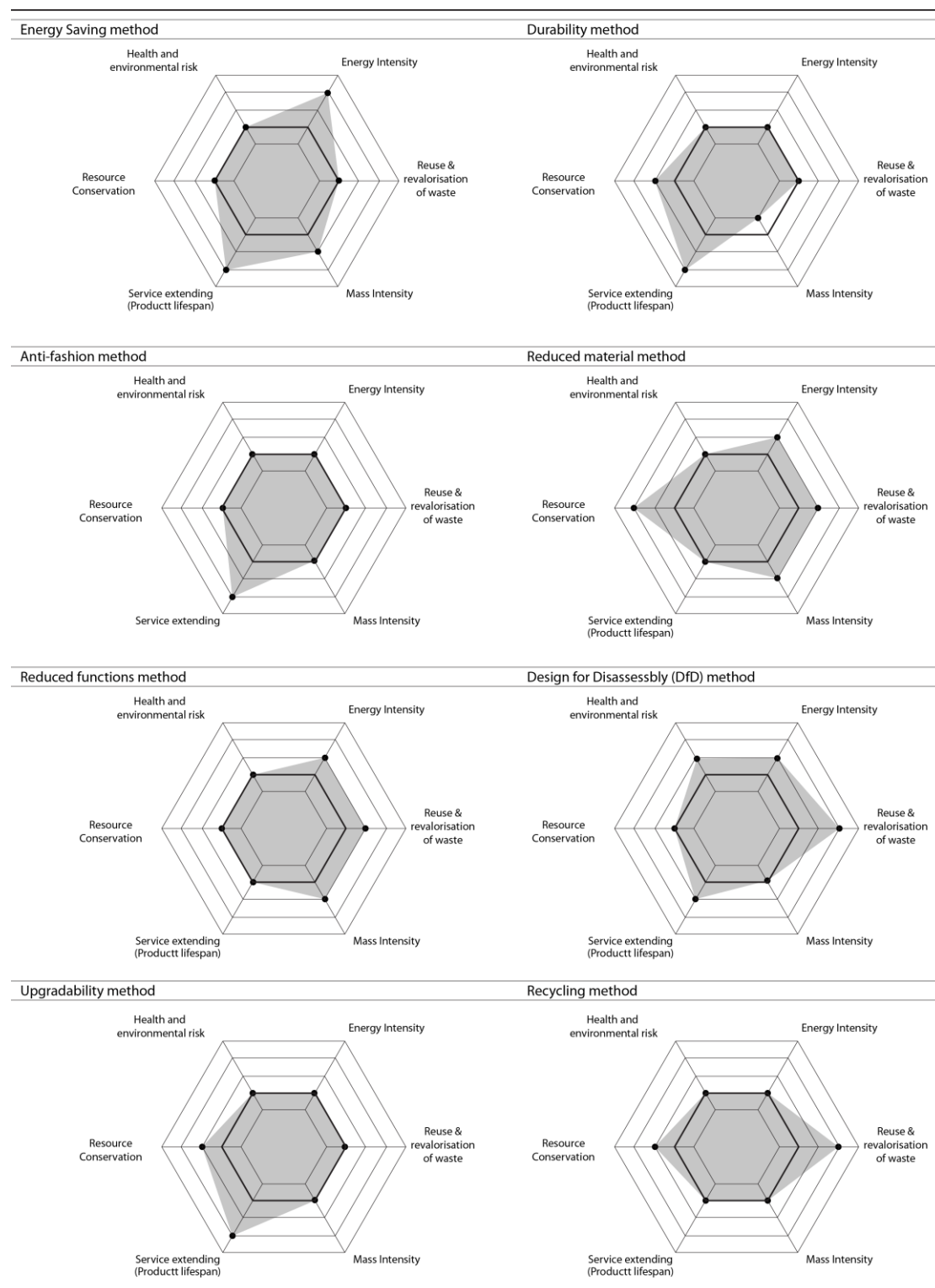


Figure 9.9 research results re effectiveness of eco design methods with reflected business importance

According to these results, eight different eco design methods have shown distinguished results by strengths and features for each method, for instance, the

energy saving method strongly achieved factors of energy intensity and service extending in Eco compass and comparing this aspect to the recycling method, which was mostly achieved in the reuse and revalorization of waste and resource conservation, it is obviously distinguishable. The points on these results were based on LCA data in appendix 6 and UL110 data, which was applied to the structure in section 9.2.

In these results, DfD, reduced materials and the energy saving methods were on average the most effective achievements from a business perspective within the eight eco design methods. In contrast, anti-fashion and reduced function methods had the weakest achievements because this analysis was undertaken using the same conditions and importance ratings; therefore in section 9.5 the eco design results reflect different scales of investments, which may deduct distinguished results.

In these results, energy saving and the DfD methods were more effective in the Health and environmental risk in Eco compass. In the Energy intensity category, the energy saving method was the strongest because the design approach was focused on the battery efficiency and managing energy consumption during the student pilot study. Consequently, the importance of energy consumption management is also a high priority requirement from markets and users through previous sections and interviews within this research, this method may be the potential approach for suggesting new solutions to increase efficiency of energy consumption from an industrial design perspective.

Looking at other categories, anti-fashion, upgradability, energy saving and the durability methods had more effect on service extensions through different achievements such as in the case of anti-fashion, this method is more focused on marketing perspectives rather than applying new environmental technologies hence, to apply and select these methods service providers and mobile phone manufacturers need to consider and understand features and expected results in major areas. Energy saving and the durability method, which are based on using new R&D approaches and innovative materials and technologies to extend product

lifespan through physical development, may be more suitable for manufacturers rather than using the anti-fashion method.

9.5 Deducting results for environmental effectiveness depending on the different scale of investment

This section will illustrate the effectiveness of eco design methods, which were deducted in section 9.4 by applying different investment scales.

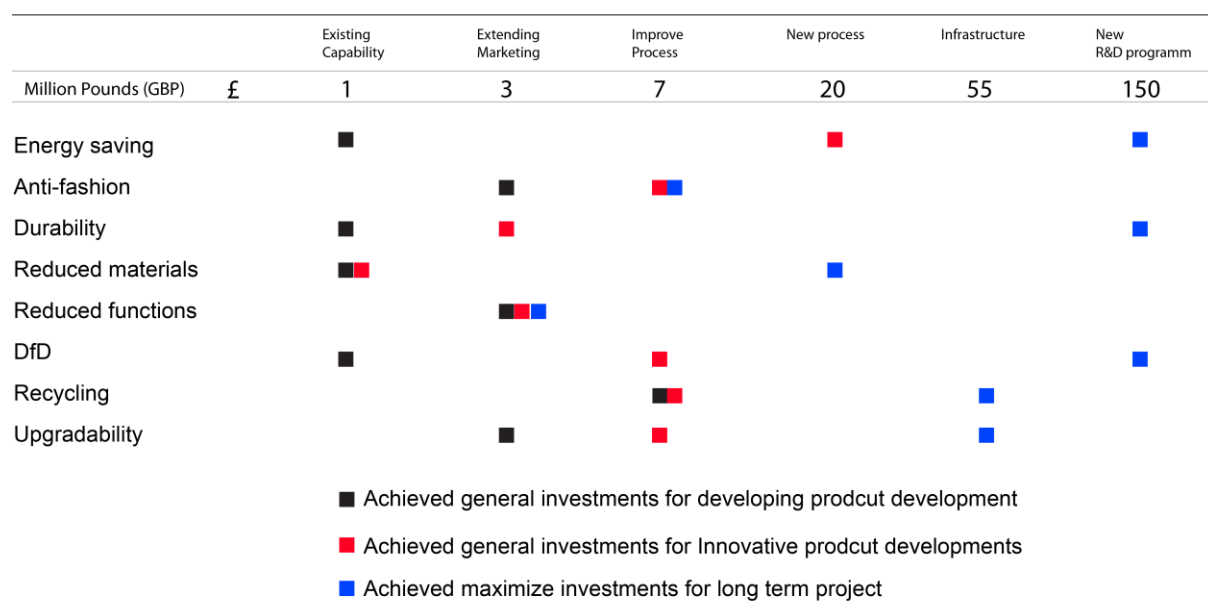


Figure 9.10 Different scales of investments based on step costs

This figure shows the different range of investment for undertaking eco design projects and collecting data for the investment. The author interviewed marketers, designers and R&D engineers within Korean mobile phone manufacturing and Korean service providers. According to the results, the energy saving approaches have historically accomplished extending capability categories, which only focuses on short-term product development. However, this area developed within the larger investment phase when developing new processes and undertaking the development of new paradigms for product innovation; currently increasing the importance for environmental factors, which reflect market demand such as higher efficiency for power consuming batteries.

Looking at the reduced functions and anti-fashion method, all types of investment for these methods is located on the 'extend the marketing' because historically there are few experiences, when applying these approaches to product development in the Korean mobile phone industries. However, among the responses from the interviews, recent large scales marketing approaches have achieved 'extending product service' and 'lifespan' hence, this approach has similar outcomes to anti-fashion. The answers also asserted that although the anti-fashion method would be applied to product development, large-scale investment cannot be achieved and also this method may mostly be used as a marketing strategy.

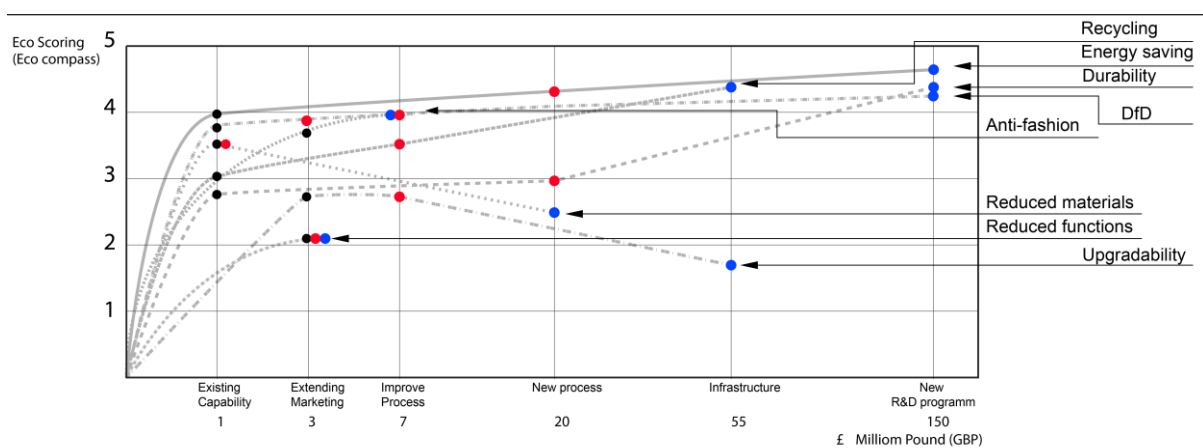


Figure 9.11 Results for the effectiveness of eco design methods reflecting different scales of investment

These results illustrate that the effectiveness of eco design methods were reflected in the business aspect when compared to different ranges of investment. These analyses were based on LCA, expert interviews and collecting results regarding effectiveness of eco design methods within the business area, see section 9.4.

According to figure 9.11, the energy saving method can produce the most effective environmental and business effect from all of the eco design methods in the long-term investment plan. New R&D programs in particular, have a higher ranking in the short-term investment category, New R&D program could show that the environmental issues, which also concern the market and commercial sides occur as higher reasons for investment.

The durability method also gained higher points. the same as energy saving, however according to the marketers and R&D engineers who participated in the expert interviews, they asserted that the durability method required greater investment than the energy saving method because this needs to develop higher values for new environmental materials or alternative materials, which are more environmentally friendly and also have economic benefit. Furthermore, to achieve this benefit requires several stages of newly developed materials. For example, to use Carbon and Magnesium, which are non-metal but have a lighter weight and are harder and stronger, it requires special facilities to treat and produce these materials and also specific knowledge.

When reviewing the recycling method, this method could not affect the short-term investment compared to other eco design methods. That is this method that can enhance the rates of recycling by the use of recyclable materials in a short-term investment, however, as previously mentioned in chapter 2, the major barriers for current recycling systems are i) a mobile phone consists of different assembly structures from different manufacturers, ii) having difficulties with disassembly by securities of key components and iii) absence of experts and facilities for collecting and verification of wasted mobile phones. Therefore, this method should follow the long-term investments to establish the infrastructures and educating recycling experts to rapidly enhancing the recycling rate. Respondents also emphasized that effectively increasing the recycling rates needs to lead the users' to participate by providing direct benefits such as tax support and compensation services.

Although the effectiveness of the eco design method against the investment of the DfD method could not reach a higher position in Existing capability and New processes the effectiveness of the DfD method did very well in New R&D programs because according to the expert interviews, the DfD method can attain the maximum results through innovated and simplified manufacturing processes by designing new product structures rather than only considering new packaging design or assembly structures whilst using current manufacturing processes and lines.

Despite the anti-fashion method, which can have the effect of extending the marketing phase, this method may not make profits in improving processes against levels of investment. For this reason the marketers who attended the interviews in this research asserted that in the case of the marketing strategies, which require developing innovated new products such as the anti-fashion method, only focuses on the marketing perspective to extend services and product lifespan by marketing promotions without developing impact products (namely, the product can change the structure and paradigm of the original markets and the product also makes users' emotional satisfaction).

In the case of the reduced material method, it can be shown that effectiveness in existing capability, whereas the effectiveness of the tool may decrease as there are increases in the scale of investment. The major reason for this could be that if this method is applied to new product development for designing new product structures for only reducing material consumption then the effectiveness of this method may be smaller than other eco design methods which have similar purpose such as durability (extending services and product lifespan) and the DfD method (increasing recycling rates through consideration of new manufacturing processes and product structures).

The possibility of investment in the short and long-term for the reduced functions method was located in 'extending the marketing' phase because respondents answered that applying the reduced functions method would be a lower adoption rate for business because i) only specific targets use simple functions, ii) the estimated effect of saving energy would not be fulfilled because specific models using mobile phones will be limited and iii) this approach contains a high risk marketing content; mobile phone trends focus on the functional differentiations and intelligent systems. In contrast, this method would be adoptable for other electronic products, which have complex functions and require more energy consumption such as digital TVs.

Finally, the upgradability method showed higher expectations for effectiveness in the previous analysis through the Eco strategy wheel in chapter 5, however this method requires the entire structure for marketing against smaller environmental and

economic benefits in long-term investments hence, the curve differed from other eco design methods. According to this analysis, this method rapidly decreased the method's effectiveness in the 'infrastructure' phase because although developing upgradable components will increase product lifespan and extend product lifespan in the short-term, to achieve complete upgradability, requires the establishment of new types of services and markets which are based on components from finished products.

9.6 Deducted results for environmental effectiveness depending on different international environmental legislation

This section will present the effectiveness of eco design methods applying different importance for major international environmental regulation results in section 9.4. These importance rates are based on how international environment regulations impact the major markets. To generate the differentiation of six factors in Eco Compass, giving the points different importance based on section 9.1 and the gaps between each point is 0.15.

Different facts	Impact on the entire factor	Impact on part of factors	No impacts
Points	1.30	1.15	1.00

Table 9.4 standards of single points

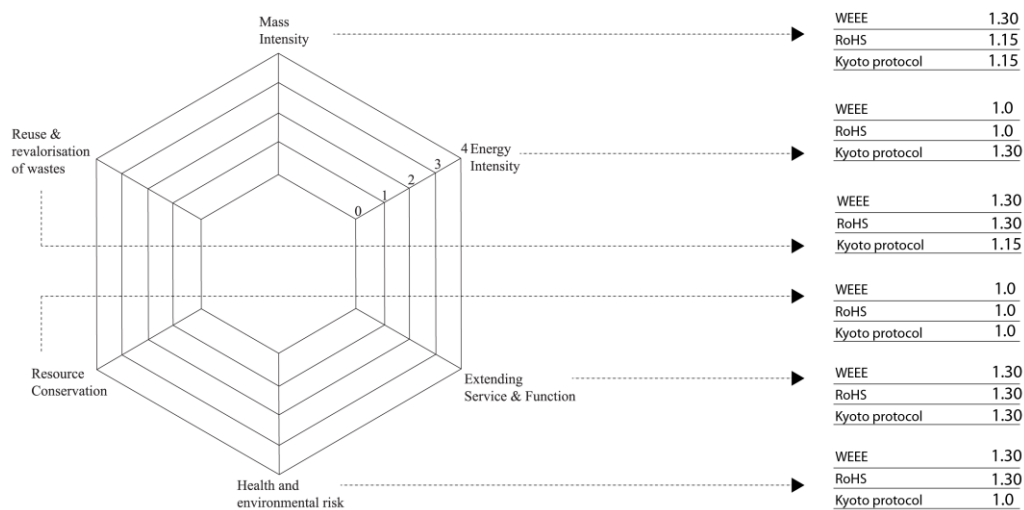


Figure 9.12 presents the importance based on applying different importance points.

Figure 9.12 shows the factor for 'Extending service and function' is the highest ranked in WEEE, RoHS and the Kyoto protocol and 'Reuse and revalorisation', 'Health and environmental risk' and 'Mass intensity' followed.

'Resource conservation' ranked bottom because these three international environmental regulations focus on manufacturers' ecological responsibilities and also these regulations considering environmental aspects in production and disposal. Hence, in the case of 'Energy intensity', research looking at EuP states this factor may become more significant but this research selected major markets for the Korean mobile phone industry, which are US, China and India.

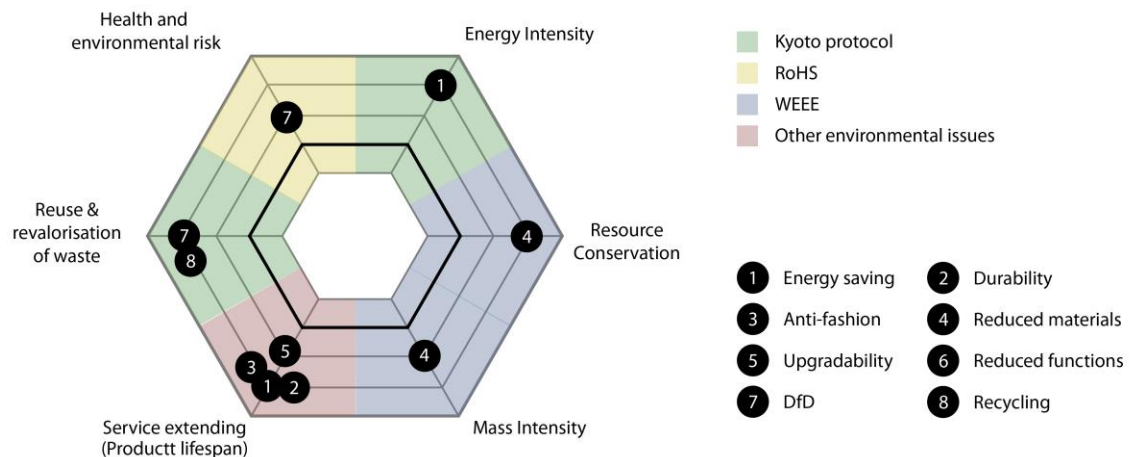


Figure 9.13 Results for effectiveness of eco design methods reflecting different international environmental legislations

Figure 9.13 illustrates the positioning of the eco design methods by different major international environmental legislation. According to this analysis it consists of four different areas which are the Kyoto protocol, RoHS, WEEE and other environmental issues (particular extending service and product lifespan). Firstly, the Kyoto protocol has two categories in Eco compass, which are Energy intensity and Reuse and revalorisation of waste, see section 9.2. The purpose of the Kyoto protocol is to control amounts of CO₂ emissions during the entire product lifespan from production to disposal and also manage the environmental standards for new products by comparing the CO₂ emissions to energy consumption and these activities will become the fundamental data for undertaking carbon emission trading. In this figure, the energy saving method is the strongest in Energy intensity and DfD and recycling methods are effective in Reuse and revalorisation of waste area. The significant reasons for its strengths are that these methods are based on efficiency such as energy and material consumption efficiency rather than improvement of recycling rates or extending product lifespan. RoHS, whose purpose is to decrease environmental and human risk by restricting toxicities in product manufacture and the Health and environmental category can be included in this regulation.

DfD is also the strongest eco design method because this method leads to the i) increase of recycling by consideration of reducing manufacturing and disposal

processes and effective disposal approaches and ii) finding better ways to manage the waste material. The purpose of WEEE is to collect the waste products or materials by providers and manufacturers, especially in the electronic and electric industries: reduced material methods are included in this field. Because there are common purposes between this method and WEEE; to decrease environmental impact and to save the costs for waste treatments the manufactures should find better solutions for material consumption.

In conclusion, energy saving, reduced materials, DfD and recycling methods are the most effective when dealing with current (three major) international environmental regulations and moreover, Korean mobile phone industries have to consider adopting these methods and to enter the Chinese and European markets; these markets are the second and third significant mobile phone markets for Korea (see sections 9.3).

9.7 Conclusion;

This research demonstrates environmental effectiveness of eco design methods and understanding relationships between environmental values and business requirements. To deduce these results, the research has been strategically undertaken through research steps including the Eco strategy wheel for defining the possibility of adoption for each eco design method (see chapter 3), undertaking student design work for applying eco design methods into the objects (see chapter 5), implementing quantitative evaluations to deduce design results (see chapter 6 and appendix 6), surveying mobile phone service providers to find business issues were related to the environment and user and expert group interviews (see chapter 8) and applying these results to Eco compass to represent and compare each eco design method by different factors (see chapter 9).

As this research has demonstrated how qualitative and quantitative environmental and business values of eco design methods have and how adopt these eco design method in product development, which had been not undertaken in design field in previous chapters. Hence, referring to previous chapters, the author had seriously difficult to find the similar researches and data, which could be related to this research and mostly previous research about eco design methods, were for finding environmental impact to use LCA and study on eco design process in environmental engineering area. That means as defined types of previous researches were i) finding and exploring environmental impacts and strength of manufacturing process or product by adopted LCA and ii) referring to chapter 5, defining the eco design methods as practical level of the eco design or design strategy.

Through these research steps, the author found these following facts:

- i. Eco design methods can influence different aspects of environmental impact by characterising its features and strengths and also each eco design method can be positioned in a different area of Eco compass through these aspects.
- ii. To apply eco design methods for product development, it requires the definition of current business demands and needs to understand present significant international environmental legislation and environmental conditions enforced on major markets.
- iii. Energy saving and the durability methods connect to business demands and is the strongest within the entire eco design method, have historically applied product development by different aims in various manufacturers.
- iv. To apply eco design methods, the application process should include the quantitative evaluations such as LCA to verify objective environmental values.
- v. To produce increasing business values for the eco design methods requires combining different eco design methods to achieve the same purpose and this can be done through multiple points in Eco compass.

vi. Business issues connected to the major Eco compass categories, which are Energy intensity and Service extending, however Service extending did not involve any international environmental regulations directly.

vii. To implement eco design methods effectively requires consideration for environmental effectiveness (section 9.4), values of business perspectives (section 9.5) and needs to reflect relationships with international environmental legislation (section 9.6) and moreover it also needs to consider establishing a manual to avoid difficulties during the implementation of eco-friendly product development by designers, marketers and engineers.

viii. According to chapter 3, to overcome the various traditional barriers of eco design implementation, eco design requires a combination with business enterprise to produce environmental and economic benefits, and also needs to find the connection points between environmental demands and markets' requirements but also establishing the consumers' trust about eco-friendly products and government supports to stimulate eco product development.

Summary of chapter 9

- Through a process of cross comparing environmental and business effectiveness, it is possible to consider how related market demands and technologies circumstance are addressed by the application of eco design methods
- Although eco design method achieves the biggest reduction of environmental impact, it similarly has to reflect commercial enterprise targets and the necessary success of realising projects
- Energy saving and durability methods were the most realisable eco design methods as these achieved a direct understanding of user demands in mobile phone industries
- Mostly eco design methods have been impacted on extending capacity in different level of investment however after 2nd level, efficiency of eco design methods made different aspects by scale of

investments, relationship with other areas and level of trend reflection

- Each eco design method can address different international environmental regulations by its specific, characteristic approaches. Therefore to enter new markets or progress the impact on existing markets, designers, marketers and engineers need to similarly understand the market contexts and environmental legislations

Chapter 10. Conclusion

International environmental regulations, which have worked only as social customs until now, have become a significant factor in deciding acceptance or rejection for trading. Global environmental actions have decided company survival and moreover, with the introduction of the 'Green Round' (Aaris Sherin, 2009) era has stimulated importance for environmental issues to become core factors for consideration within product developments. This chapter presents the significance of this research, necessities for implementing further research and limitations of the research undertaken.

In the early stage of this research, the author started to study how to undertake environmental projects in manufacturing companies from comparisons of the current eco design approaches and environmental policies to actual implementations in the industrial design field. Undertaking the primary research showed the current address of environmental design in manufacturers and the researcher found the various barriers in undertaking environmentally friendly product development through this implementation. These difficulties include i) historically, developing environmental products has not produced many successful results in the market, therefore the positioning of eco product development has given the company a sceptical response from consumers (Aaris Sherin, 2009), ii) eco product development requires a longer-term large investment, but this has only produced small economic benefits (Andrew Savitz, 2008) iii) to verify eco products requires using quantitative environmental evaluations methods to appeal to consumers (Andrew Savitz, 2008), iv) eco product development requires multiple implementations, using different approaches to solve complex environmental demand such as design, marketing, R&D and engineering.

However, these complicated and sophisticated difficulties whilst implementing the eco product development into the manufacturers, especially mobile phone manufacturers, should consider the environmental issues for trading and continuously producing (i.e. RoHS, WEEE and Kyoto protocol, which are the core international environmental regulations focused on the electronic and electric

manufacturers). Hence, the traditional paradigm of environmental design of products only follows social responsibility and cannot produce much economic benefit, it needs to combine industrial and economic fundamental principles.

Dieter Rams who is a historical German industrial designer asserted that the meaning of economic growth in the future is based on qualitative (or environmental) growth rather than quantitative growth requiring waste or resource consumption. This means that designers should consider the social and ethical responsibility for driving more recycling and reuse of materials, based on less use and less waste production (Lomborg, 2001). In addition, it also emphasises designers' environmental efforts for establishing ethical consumption culture and building new paradigms for industrial design philosophies, which considers a balance between economic, social and environmental benefit.

Consequently, current traditional environmentally friendly design principles and approaches have also re-established reflecting these markets and global demands and the standards for industrial design have been applied (Andrew Savitz, 2008).

Traditionally the standards for product design focus on the users' functional and emotional satisfaction during the product lifetime. However, environmental preservation has become the core social problem through depleting the Earth nature through developing technologies and mass production, consumption and disposal (Andrew Savitz, 2008) therefore, the original standards for industrial design combine a significant condition of 'co-existence with the environment'.

Eco design, which has been approached in this research, emphasises a social design balance between environmental factors, human benefit and economic consideration rather than traditional environmental concept design. To achieve these eco designs, requires the establishment of a strategic plan from very early stage product development to reduce energy consumption during production whilst saving natural resources (Resource Energy intensity and Conservation; Eco compass) and also finding ways to decrease the amounts of toxic emissions and wastes (Reuse and revalorisation of waste; Eco compass). Additionally, eco design also needs to

design to increase rates of reuse by developing new environmental and alternative materials (Mass intensity; Eco compass). There is a need for better solutions for building new recycling systems and approaches by objectively understanding quantitative evaluations (Reuse and revalorisation of waste; Eco compass). Eco design has to consider environmental impact during the entire product lifetime (Health and environmental risk; Eco compass) and needs to find the economic connection for marketability (Service extending; Eco compass).

Despite fulfilling these conditions for eco design, if the product disregards market trends (did not follow traditional industrial design standards that consider the usability and aesthetic achievement) then the product may disappear without success.

This research presents how to understand future paradigms for eco design by applying quantitative evaluation tools for verifying the design results, defining different approaches and features of eco design methods and adopting eco design representative methods for cross comparison through different standards of environmental perspective to provide templates for environmental design methods.

10.1 Research conclusion

This research studied analysis of the effectiveness of eco design methods within the business and environmental perspective through cross comparison approaches which established that templates for eco product development, and in particular specific industries and different ranges of investment and understanding business aspects through different features and strengths of each eco design method.

According to chapter 3 (definitions of eco design methods in literature review) eco design or environmentally friendly design has not been able to find many successful examples in the market historically whereas the significance of this area has been magnified.

This chapter showed various barriers for implementing eco design into companies with difficulties due to a lack of eco design experts, who have knowledge regarding environmental quantitative evaluations and industrial design. It is both hard to find environmental design expert educators and there is traditional economic trouble for undertaking eco design projects. Therefore, this research focused on finding better approaches to using eco design methods for industrial designers. Applying the Eco strategy wheel in chapter 3 demonstrated how to evaluate eco design methods by reflecting various design and business fields for undertaking design work and using environmental quantitative evaluation methods, this research tried to make produce more accurate data for further steps of this research.

Through the above, the author found important acceptance conditions during adopting the methods for industrial designers.

1) The eco design methods, which have connections with traditional industrial design approaches took a shorter time to understand and learn compared to other eco design methods, which have no common content.

2) The eco design methods, which are based on developing new technologies and connecting social issues rather than traditional industrial design approaches has difficulty in understanding and interpreting languages.

According to these conditions, eco design methods can make environmental and business effectiveness as below:

The environmental effectiveness of eco design methods are;

1) Applying eco design methods should be implemented in an acceptable range of marketability and productivity. Hence, designers should understand current environmental technologies and environmental demands of consumers and markets.

2) To achieve the application of eco design methods for product development, environmental quantitative evaluations should be done to produce environmental

values. This provides the fundamental proof of environmental verifications and also demonstrates environmental core problems from the results of environmental evaluated current design objects.

Effectiveness of eco design methods from a business perspective are reflected below;

1) To effectively adopt eco design methods requires selecting appropriate eco design methods using different ranges of investment and purposes for implementing eco design development because eco design methods have distinguishing features and strengths (this may occur through different industries) of each eco design method therefore to apply eco design methods, requires an understanding of the contents of specific industries, where the eco design method is applied to the character of the market.

2) To implement eco design methods within product development requires an understanding of current international environmental legislation, which influences particular markets. Referring to section 9.6, each eco design method can be connected to different major international environmental regulations hence, to produce more effective eco product results in economic and business terms, designers have to understand the content, issues and major influences of international environmental regulations.

In conclusion, this research has studied environmental / business effectiveness of eco design methods through combining academic and practical studies. These methods have been influenced by outside factors such as ranges of investment, consumers and market conditions and different regional acceptance for international environmental regulations. Therefore, to adopt the eco design methods for product development requires an understanding of specific areas and the strengths and characteristic features of each tool, and then these methods may gain value for the environment and for business. To find the environmental and business values through this research will provide the environmental guideline for industries. Korean mobile phone manufactures such as Samsung and LG have become the world class

manufacturing companies however these companies also have faced the difficulties at environmental friendly product development by obstacle of create benefit and burden investments. Therefore, this research will show how and what approaches can be used for depends on types of environmental friendly product and what process can be adoptable by different situations.

10.2 Further research

This research has four different pathways for further research.

Firstly, it needs to extend the range of research objectives for other electronic products to find and verify the appropriateness of eco design methods and hence acceptance.

1) From this further research, which may include undertaking different ranges of energy consumption and scales of product specifications such as digital televisions and refrigerators (this may prove the general appropriateness of eco design methods).

2) The further research requires the implementation into a wide range of industries, ie: transportation industries and other types of manufacturing (non-electronic products to get more accurate data).

Secondly, to produce the quantitative data requires the application of actual environmentally friendly product development in order to compare research results, research results of eco design effects on the environment and from a business perspective. This further research will provide comparable data between research and field data and through this will find various core factors and causes.

Thirdly, to understand more about eco design methods requires the analysis of other impact from social and cultural factors. Eco design historically has been developed through social responsibilities and this has been developed by different nations,

markets and industries. Hence, eco design methods require consideration to reflect these cultural and social differentiations to each eco design method and find the effectiveness related to each perspective.

Fourthly, further research needs to target other countries' mobile phone manufacturers as a control group for comparison. To implement the research requires an understanding of the different environmental and industrial agendas and issues for each country and through this research will provide eco design methods pallets, which have more templates for increasing rates of adoption for the mobile phone manufacturers.

10.3 Research limitation

The limitations of research can be divided into limitation of research implementation and limitation of research process.

Limitations of the research implementation mostly occur in undertaking the LCA method to analyse design results by quantitative environmental evaluation and finding participants for expert interviews. Firstly, the difficulties of applying LCA in this research were i) LCA is based on evaluating existing and completed products therefore to make inventory lists for each design result needs objective standards (see chapter 3) this part of the research was the most difficult and complex phase. ii) LCA requires accurate data from resource collections to disposal (amounts of emission waste) whereas the feature of the mobile phone industry has the highest security level of embodied technologies and manufacturing processes, therefore further research requires more accurate manufacturing processes and shipping costs and distance for resource collections. However using LCA as a qualitative approach to analyse design work provided possibilities for adoption to the design area and requires environmental experts in an in-house company to increase environmental value.

Undertaking expert interviews in this research needed more samples from related mobile phone industries such as recycling centres, outsourcing companies for manufacturing mobile phone components, NGOs and the same samples from other companies, therefore further research requires more FGI for getting more information regarding barriers and potential environmental achievement.

Limitations of the research process for LCA, Eco strategy wheel and Eco compass are not related to the traditional industrial design hence, to stimulate producing the quantitative evaluations for environmental design work, the environmental evaluation methods can compromise to reflect traditional design perspectives and also needs to develop new innovative methods for designers. For instance, this author also had difficulty whilst undertaking LCA evaluations to understand the program, environmental engineering languages and engineering based approaches. In conclusion, to increase the eco design and environmentally friendly product development in manufacturers, the various programs such as evaluations, idea generations and verifications need to extend to users by using understandable languages and considering usability factors.

10.4 Research implication

To implement this research, the author used the TBL (Triple Bottom Line) theory, which is a fundamental philosophy of Sustainability (see chapter 3) and emphasized a balance between social, environmental and economic benefits to make sustainable societies and environments. This research has three different perspectives for the research results; environmental, business and international concerns (adoptable possibilities of eco design methods centering on major international environmental legislations).

10.4.1 Research implication in an environmental perspective

Previous research in chapter 9 demonstrated the environmental effects, which occurred through applying eco design methods to product development, such as leading higher rates of reusing material (recycling method), saving energy (energy saving and reduced functions method) through increasing energy efficiency design, reducing material consumptions (reduced material method) through innovative assembly and disassembly structures and developing alternative materials, achieving simpler production processes to decrease waste and designing disassembly structure to increase recycling rates (DfD method), extending product lifespan by repairable, attachable and installable components (upgradability method) or reinforcing product structures and materials (durability method) and finding longer emotional fulfillment by creating new paradigms for products or different types of marketing approaches (anti-fashion method).

These methods consider current and potential quantitative environmental impacts and can be distinguished with traditional environmentally friendly design approaches that have been focused on packaging materials or product housing design. Therefore these methods can reflect industrial demands particularly electronic and electric companies, which are strong under the control of major international environmental legislation since the Millennium in the Green Round era (see chapter 2 and 3). The implication of this research suggests better methods for specific industries and narrow focused environmental categories through the establishment of templates for eco design methods, based on the different rates of effectiveness of eco design methods' characteristic features.

10.4.2 Research implication from a business perspective

The implication of this research from a business perspective shows the conditions to produce the TBL (Triple Bottom Line in Sustainability) balance between social, environmental and economic benefits to build a direct relationship with

environmental preservation, businesses and demonstrated structural implementation, which found current environmental barriers for designers and business, undertaking design work, evaluations and surveys to produce the business connection points.

Consequently, this research introduces various eco design methods to increase the efficiency for undertaking environmentally friendly product development and eco designing for manufacturers, particularly in electric and electronic companies via this research. In addition, this research demonstrated how to apply quantitative environmental evaluations for the design results through experimental approaches and found significant conditions for designers and also problems such as interpretation and misunderstanding during the undertaking of eco design projects. These implementations of the research started from the gaps of differentiations between traditional environmental products and market and consumer trends and this research will provide suggestions to companies for more quantitative and objective approaches and introducing distinguished effectiveness of eco design methods through reflecting different agendas.

10.4.3 Research implication for academic value

This thesis consists of 10 chapters including an introduction and conclusions. Each chapter has a strategic role in the research process and relates to the previous and following chapters.

These are abstracts for explaining each chapter.

This thesis has two chapters for background research through literature reviews. Chapter 2 illustrates the increasing importance of environmentally friendly product development and general definitions for each eco design method, finding strengths and features of the eco design methods in chapter 3 through literature review. In chapter 4, the author estimated the maximised influence of each eco design method and drew major issues with different content such as extending product lifespan, increasing efficiency and raising user satisfaction levels for eco design methods and

also considered core influences to different user types. These implementations provided background data for cross comparison to environmental evaluated data by LCA and Eco compass in chapter 9 and moreover, in further research, to establish clearer and more accurate data it can be a set of guidelines for producing different factors to generate gaps between estimated and evaluated results.

Chapter 5 shows the structural research methodologies and found core research as reference for undertaking various academic studies such as interviews, student design work (group design generations) and environmental evaluations (LCA and Eco compass). Chapter 6 established the strategies for applying LCA and illustrated eight design results from student group design work and chapter 7 undertook LCA and showed simplified LCA results (more information about LCA results in appendix 6). In chapter 8, the author implemented experts' and general mobile phone users' interviews to find various that occurred during mobile phone usage and purchasing. In chapter 9, the researcher positioned eco design methods in different conditions of influence that are i) environmental categories in Eco compass to deduct the different impacts of environmental phases, ii) reflected business importance to environmental effectiveness based on i) arranged eco design methods within international environmental legislation.

To deduct the research results as previously mentioned in section 9.4, environmental impacts were defined in six environmental categories, based on Eco compass and were based on the environmental quantitative evaluations (using LCA, which is a quantitative method as a qualitative approach, see chapter 3) and UL110 was used to attain more objective results.

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Appendix_1

University of Salford

Working Title: Environmental Design- Approaches to Environmental design within the Korean electronics industry

**Young-Yun Kim
greendeisgny2k@gmail.com**

Questions. (English)

Interview target: Special List (Professor/ Researcher of Kookmin University, Seoul University Research Centre)

(Test questions)

How long have you studied environmental friendly subject?

Why important is environmental friendly technology? What is the reason to study environmental friendly design?

(Blanket questions)

What is effective environmental friendly technology?

How has the environmental technology of Korea coped with global environmental issues effectively?

What does the Korean ET(environmental technology) mean?

(Detail questions)

What is Korean environmental friendly technology to consider Korean features (economic structure feature, geographical feature and cultural feature)?

What and how effort have Korea companies been doing to develop Korean environmental friendly technology? What and how effort has Korea government been doing to develop Korean environmental friendly technology?

How have the Korean large companies recent dealt with contamination materials came out in manufacturing, using and disposal? According to “10’s technologies to rule in 21 century” in the 21century, the role of ET(Environmental technology) with IT(Information Technology) and BT(Biology Technology) in getting increase.(10’s technologies to rule in 21 century, Hyang-Nam Choi ,2005) Why is the Korean environmental friendly technology important?

ii. Economy base questions

(Test questions)

In the future, what factors will international and domestic economy be influenced?

What is Korean economic principle?

(Blanket questions)

What are Korean economic features?

Culturally

Geographically

What is the environmental friendly product to consider economic part? Considering Korean economic structure, how to improve the environmental friendly products?

Generally the developments of environmental friendly products need more budgets.
Why do the companies have to develop it to submit loss?
(Detail questions)

How does the environmental friendly product develop to reinforce the economic part?
Many environmental problems have been occurred during disposal and collecting the waste by the companies' economic problems. How does the environmental friendly product and policy change to deal with? What is the efficient environmental friendly policy?

Considering Korea economic features, international environmental preserve restrictions will be a kind of trade wall. How do companies and government effort to overcome?

In the economic part, what benefit and loss does the environmental friendly product development bring?

Long term

Short term

iii. Costumer base questions

(Test questions)

Have you ever used or got a environmental friendly product?

If answer is "Yes"

Why did you buy or use?

What is the different with other products? Outside? Function?

How did you get it? If answer is "No"

Why not?

Where can people buy a environmental friendly product in Korea?

(Blanket questions)

How about purchase recognition rate to the environmental friendly product?

Have you ever seen the successful environmental friendly product in Korea?

In the Marketing /In the Manufacturing/ In the Selling

What factors does the environmental friendly product need to develop to succeed in Korea?

(Detail questions)

How percent do Korean consumers know about the environmental friendly product?

Ordinary times, have you seen the environmental PR or advertisements through the media or mass communications?

If answer is "Yes" then Where? How?

What kind of product?

Comparing the environmental friendly product with normal electronic product

Price point? Product quality? Costumer target?

How many Korean do they understand international environmental restrictions?

University of Salford

Working Title: Environmental Design- Approaches to Environmental design within the Korean electronics industry

김영운(Young-Yun Kim)
greendesigny2k@gmail.com

Questions. (English)

Interview target: Senior Manager (Senior Manager/ Head of design office)

i. The hierarchy of corporations
(Test questions)

How long have you worked in this company? For 22 years and 8 months

What are your responsibilities in the design process? Managing from project plan to final design stage

(Blanket questions)

How does your company structure deal with cultural issues effectively? I think now we are dealing with quite effectively. Particularly if it can contribute potentially to the market then support positively from design plan stage.

How does your company structure improve? Recently company has special team we called DB(Digital Board), CA(Change Agent) so designer's idea and suggestion deliver to Top management via them. Especially CA, who they are consisted by company structure and culture specialist, has been leading the company to better atmosphere.

(Detail questions)

How does your part communicate or decide with other part?

Product plan -> marketing -> research centre -> designer meeting and travel on a business Internet e-mail, Video meeting

We have got very often meeting so we can solve any communication problem.

How often? Basically depends on the project however we have got regular meeting. Why? Because LG is not just a company for the domestic market. Most of our works have worked with global consumer demand. So we have to consider time difference and location circumstance.

How do you solve within the communication obstruction? Time difference and location circumstance are the biggest problem so we use e-mail and video meeting. What is the trouble in the communication? Miss understanding from language problem

How do you communicate with higher or lower level people? Usually Top managers go round the field and at that time, they have got a simple report by face to face and also their project jointly with designers for finding the communication solution.

Why? It is LG system for the faster decision.

What is the problem in this system type? It is difficult to do the detail or sensitive communication and is dependent on Top managers' instantaneous judgment
What are the advantages and disadvantages in this type of system? It can make the smooth communication from Top manager and quick decision.

ii. The corporation policy decision and decision maker
(Test questions)

What is the environmental friendly design policy or strategy of your company currently? 3R, and we build it by each regional environmental standard.

What factors influences corporation's policy?

Outside factor - As I told before LG is a global company so we have to listen different consumer's demand and each regional standard.

Inside factor - Project evaluation based on the above content.

(Blanket questions)

Who is the decision maker of the corporation policy and design policy?

LG Electronics=> "Design minded company"

Design policy is one of the most important factors in the company strategy and also design is one of managing strategy.

Does the design policy change when the company policy change? Yes, many times they changed together.

If so how?

Why? Design works on the main factor in company managing strategy.

How fast does the design policy change?

How frequently does the design policy change? Most of them have changed and reviewed every quarter of a year.

What factor can the design strategy be changed? There are many factors but the most significant factors, which influences to change design strategy are Brand strategy, Innovation policy and Resource.

(Detail questions)

When the decision maker or strategy is decided then what procedures does it take to make a result? We do the TDR(Tear Down Redesign) presentation to Top management commitment.

Generally after deciding of the policy, how long period does it take to make a product?

Generally spending between three to nine months.

How does the corporations' policy influence to the design? It makes the situation to change the design strategy.

What effect does the design part influence to decide the corporations' policy? Design provides different Brand Positioning.

iii. Environmental friendly design

(Test questions)

1. How designer can the environment preserve? Designer has to have 3R mind and nowadays they have to consider about product structure, material and manufacture way.

2. Has your company ever produced or made environmentally friendly products? Yes

2.1 If answer is "Yes"

2.1.1 What was a problem during a product-developing period? I think the most of large sized companies have the same problem.

As you know, environmentally friendly project need more cost and product difference between their project plan and realization during the producing.

What was the benefit for your company through that kind of project? Building stable merchandising situation via getting the product standard in objective company.

If answer is "No"

Why not?

How do your company cope with many environmental restrictions?

3. Do you know environmental restrictions like "WEEE" or "RoHS"? Recycling duty of deserted electric home appliances and general factors to restrict harmful material.

(Blanket questions)

1. Did your company use a method to develop the environmental friendly product currently?

1.1 If answer is "Yes"

What tool does your company use? Sigma 6

Has it developed by your company-self? Or adoption?

If it developed from an inside then how?

If it adopted then where it from? This was adopted from GE however now we have modified and reinforced by ourselves.

1.2 If answer is "No"

1.2.1 Why not?

1.2.2 How develop the environmental friendly product without the method?

2. Does this method work relevantly to Korean market or industrial system?

2.1 If you think positively than

2.1.1 Why do you think so? At the entire process focus, this tool reconsiders a inferior product.

2.2 IF you think negatively than

2.2.1 What is the reason?

IF your company has not any environmental friendly development method than how can your company develop, evaluate and analyze an environmental friendly product?

(If answerer can answer about "Test Question No.3) How does your company deal with these kinds of restrictions efficiently?

(Detail questions)

Generally the environmental friendly project takes more time, budget and effort. How does your company normally take budget and time to compare with normal electronic product and how do you estimate the result? We calculate average to translate to the process and now the environmentally friendly project is not a choice it is a essential factor.

Obviously "the environmental friendly product" can be defined as environmental friendly in the manufacturing, in the using and in disposal. What is the focus when is your company planning the environmental friendly project? Half percentage producing and other half is disposal.

The World include Europe, many environmental preserve restrictions have been coming through the international organizations. The other hands those are kinds of the trade wall to take aim Asian electronics companies. How does your company deal with those restrictions? We obtain the restriction content and time schedule before. Sometimes we get the information 5years before.

Has your company developed any environmental friendly product? If answer is "yes" then let me know that what was the focus to develop, what was the issues to cope with and what benefit company got.

The problems, which the produce technology and cost by a refrigerator heat insulator regulation.

We are using zinc die-casting, 6 chrome and substitute material and developing by the chrome coating regulation.

Appendix_2

Designing mobile phone by eco design methods –

Designed by 25 students in Kookmin University

	Number of participant	Subject	Period	Place
Context	25 students	Design work through Eco design methods	Jan 2008	Kookmin University

1.1 Design Program Format

A. The researcher provided table for designing to students. This design sheets were decided size of product and spec.

Kookmin University - Eco design program
■

Top View

Left side View

Front View

Right side View

Rear View

Bottom View

Name of Design Method

Name of Designers

Number of Drawing

Major Material

Design Concept

Design Feedback

Kookmin University - Eco design program
■

Top View

Left side View

Front View

Right side View

Rear View

Bottom View

Name of Design Method

Name of Designers

Number of Drawing

Major Material

Design Concept

Design Feedback

Durability

김 상 윤, 성 정 기, 김 경 윤

1/3

Natural Rubber, PE

이 디자인은 새로운 재질과

물리적인 강화를 위한 새로

무게가 무겁지 않도록 본 디

또한 제품의 형태가 너무 투

Picture appendix 1.1 Format for eco design program

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- B. The author taught them for 1 hour about eco design methods and divided them to 8 teams. Teams were consisted of 3 different levels (fourth, third and second year student) of students.
- C. Kookmin University provided 4 seminar rooms so the researcher divided space to provide to each team to work independently.
- D. Prof, Chung Do Sung also attended this experiment as a judgment of students exercise.
- E. Standards of judgment were 1) possibilities of realizations and 2) conformed eco design guideline.
- F. Designing spent 3hours and Prof. Chung and I collected 8 different types of ideas.

1.2 Design Guideline (Design Conditions)

In order to generate different ideas by 8 eco design tools, the author made design condition to help designing for them. This condition will also help to LCA analysis & Eco – compass by estimated data in advance such as product weight, scale and sorts of inserted materials.

This condition has 15 lines and 3 to 5 lines for each design methods.

2. Condition of design guideline

- A. The mobile phone has to have the same functional spec.
 - Originally the mobile phone spec was the same but through eco design method, mobile phone abilities may change.
- B. The mobile phone has to be the same size and weight.

- However except Material reduction may change weight logically.

C. The mobile phone has the same amount of battery consumption per hour.

- Amount of battery capability has to be same but if design demands extending battery physical size then capacity will extend as well.

D. Using alternate material, which will apply instead of current resource it has to be recent existed.

E. In this program will not allow using alternate power such as any free energy and solar power.

F. Product has the same product lifespan.

- Physical product lifespan is 1year and 6 months (No consider user's behaviour).

- Outside factors such as contract expiry (18 months to 24 months).

G. Type of mobile phone user has to be the same.

- Using behaviour of a mobile phone has to be the same.

H. The price of the mobile phone has to be the same.

- No cheap phone and no high-end mobile phone

I. Designer has to avoid considering other functions such as camera and MP3 player.

- This mobile phone design program only focuses on communication function.

J. Designer has to understand their role of design aim.

K. Designer has to think about inside & outside of mobile phone housing.

- Mostly design has been undertaken housing of product but in this time they have to estimate about changing product capabilities.

L. The mobile phone will not be influenced by contract.

M. Designer has to consider realization and cost of development.

N. Keys layout and position of LCD cannot change without logical reason.

O. Mostly design has to follow design guideline however if designer has idea and it has to change then Prof. Chung and the author will decide.

3. Conditions for Each method

1) DfD (Design for Disassembly) Method

A. DFD has to consider production and disposal areas both.

B. Designer has to think about structure and joints for attachment between all parts at once.

C. Designer has to consider about Size and shape of PCB.

2) Material Reduction

A. Material Reduction is not only reduction material it also needs to find better material and structure to reducing material.

B. To undertake this method needs to know character of material.

C. Designer can use combination material such as natural plastic with vegetable fibre.

4. Designer has to think about weight as reducing material.

3) Energy Saving

A. To do only Energy Saving design method is very difficult to expect to achieve it however it can suggest reduction way to save power.

B. Changing mobile phone design may influence user behavior of using mobile phone.

C. Designer cannot change capability of battery however they can change size of battery and its capability will also change as size changing.

4) Durability

A. Aim of this method is not only considering reinforcing housing but also needs to think about material and structure to make stronger strength.

B. Designer has to think about outside factors, which can broke the mobile phone.

C. Durability has the limit of extending, it means design cannot extend product lifespan to too long.

D. Designer cannot apply too futuristic material such as multi sensorial material.

E. Designer cannot use too expensive material or too difficult getting or using material.

5) Reduced Function

A. Designer has to think about priority functions and contents. To undertake this method, designer has to make flow chart before.

B. Designer needs to consider interface also because if Reduced Function may reduce too much then the product will lose its original ability.

C. Designer also needs to know user's behaviour to use mobile phone.

6) Upgradable

- A. This method needs to functional upgrade and also contents as well.
- B. The most important aspect of this method is stable condition and extension. It means design has to consider solutions that finding how to attach new technology and what contents can solve to install it.
- C. Designer needs to find the easiest way for inputting new technology to mobile phone.
- D. This mobile phone has to connect to new device or PCB directly.
- E. Idea of this product is extending product lifespan through upgrading but also this may open new types of mobile phone that from selling mobile phone to components. Therefore designer has to consider about this aspect.

7) Recycling

- A. Recycling design method needs recyclable material.
- B. Designer doesn't need to consider collecting system or tax re-funded.
- C. Designer has to think about disposal to make easier recycling.

8) Anti-Fashion

- A. Anti-Fashion requires research data about consumer's standards to selecting mobile phone but in this time we will use Nokia 1100 model as a reference.
- B. Designer only needs to concentrate on finding authentic mobile phone.
- C. Designer has to forget about current mobile phone shape and functions.

4. The list of Questions and Feed backs from the participant.

During doing this program, students had various questions and feedbacks. Questions can be divided to 4 areas.

The researcher choose these questions by frequency of asking.

5. Questions

A. Appropriateness of Eco design methods

- Why does company need to do eco design?
- Do you think LG and Samsung will adopt these methods?
- How can we know the result is eco friendly or not?
- What are the differentiations between product design method and these?
- The researcher hasn't heard eco design method in her whole life. Do they actually work properly?
- The researcher think usually "Eco design" or "Eco product" have not worked economically. So many Korean companies dropped or gave up developing eco product. Then how is eco design going to be?

B. About particular eco design methods

- What material can I use instead of plastic?
- Is there any product that is designed by DFD?
- I think Energy Saving is not design tool, how can it be this in design area?
- Anti-fashion is not design method. Because I have learned design has to provide aesthetical satisfaction to consumer but this method is not enough to give it.
- If I use Anti-fashion design method then the shape of mobile phone will not change much.
- To do Anti-fashion requires quantitative interpretation research data then how emotional facts evaluate?

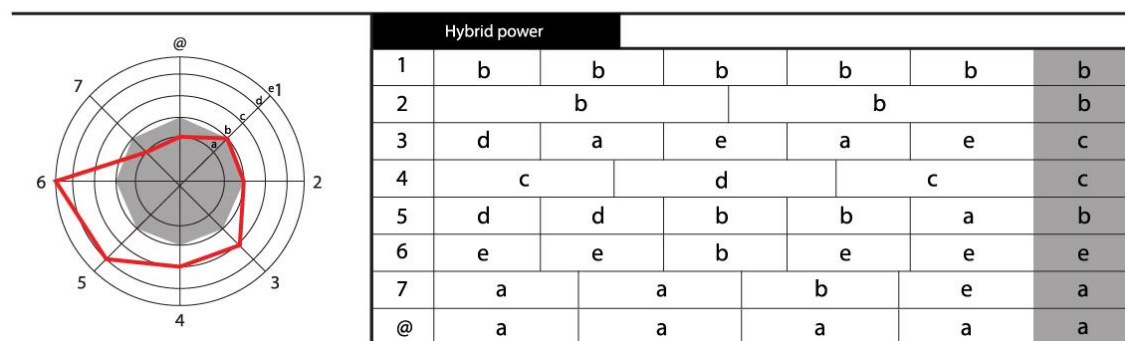
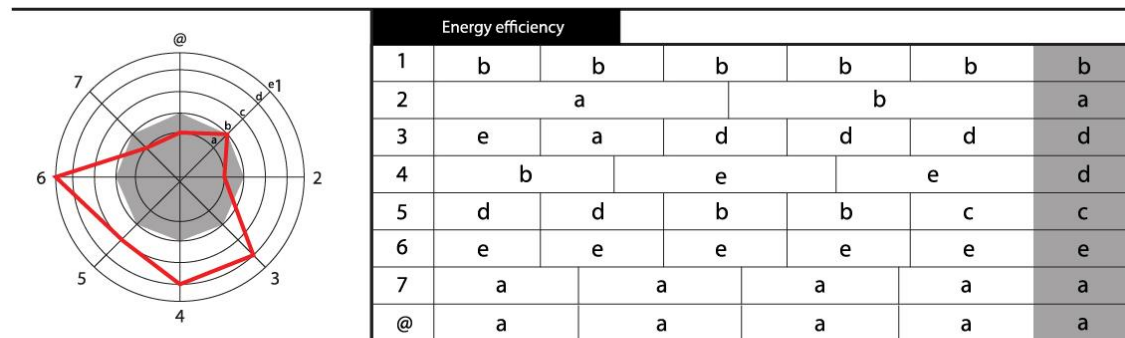
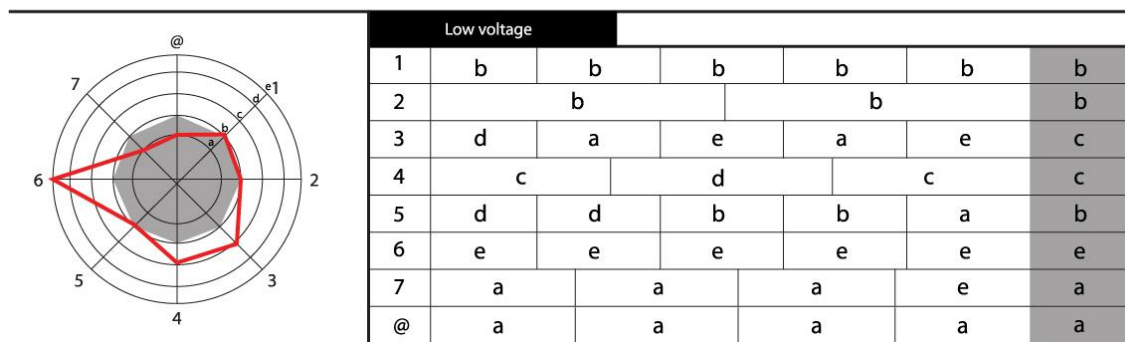
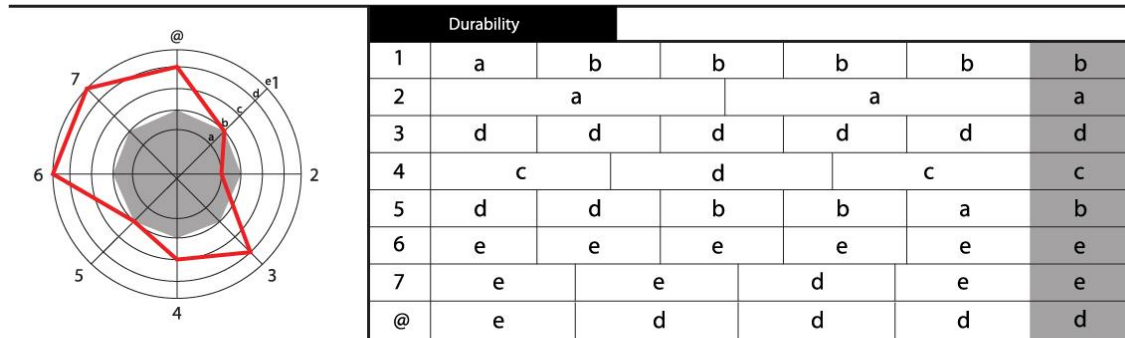
C. About differentiations of eco design between Korea & UK

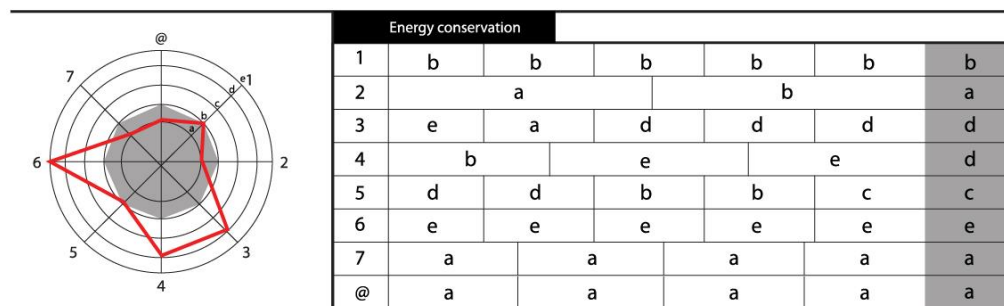
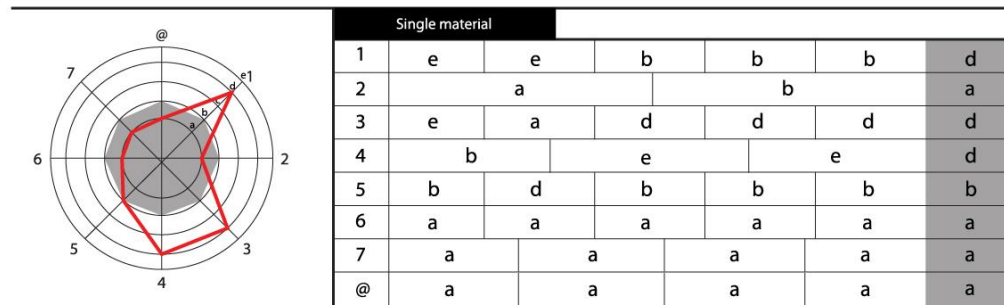
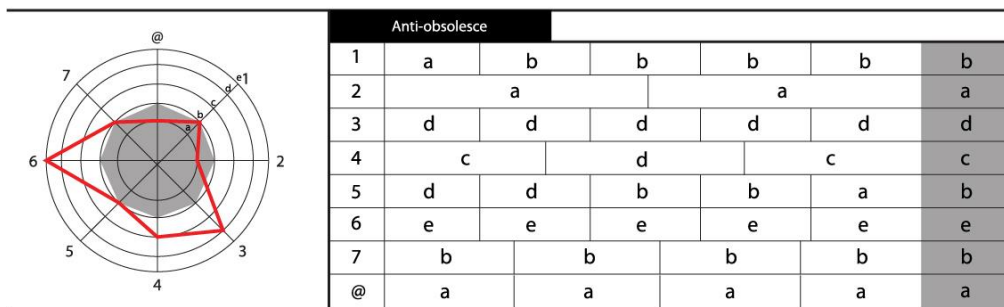
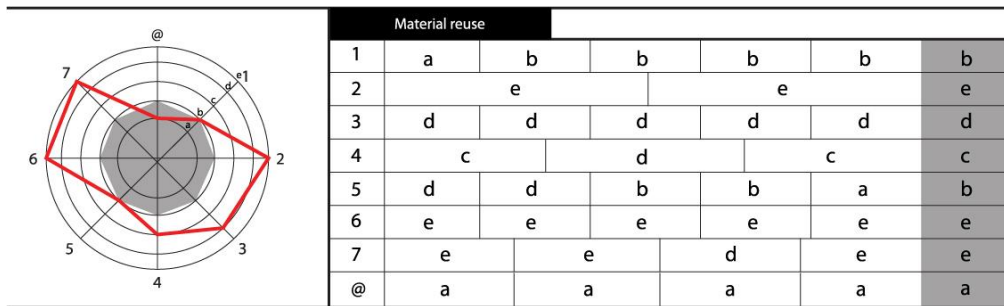
- Current eco design in Korea is focused on campaign or developing conceptual product in terms of effective PR however these design methods are not seems for the same purpose.
- Do you think what is the most different things between Korea & UK eco design?

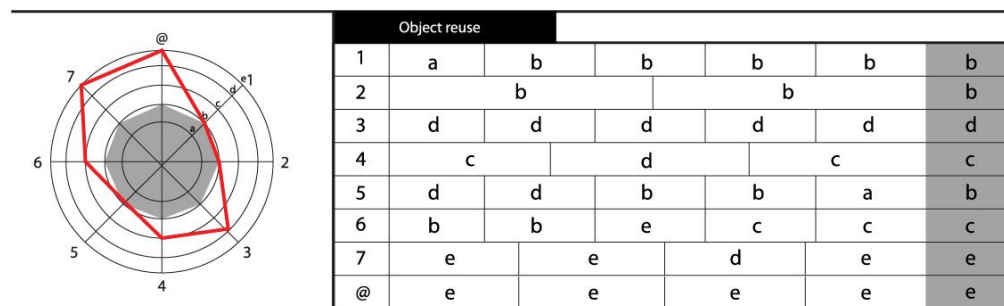
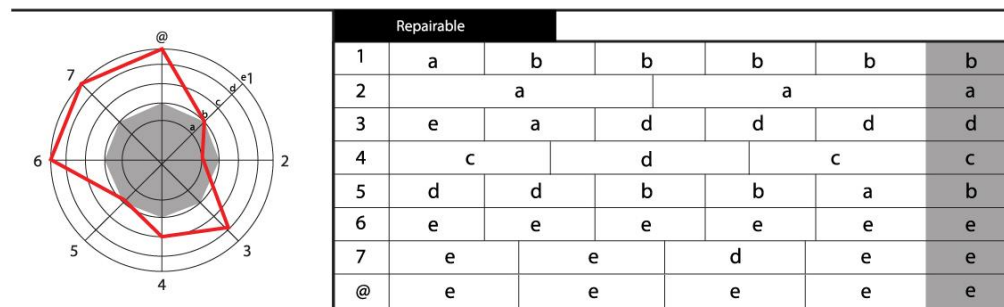
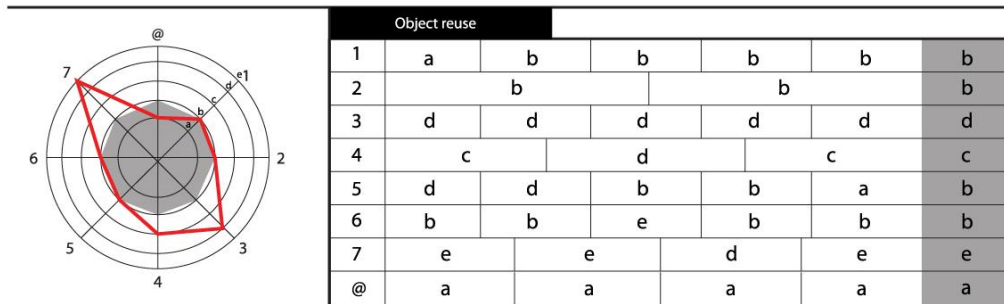
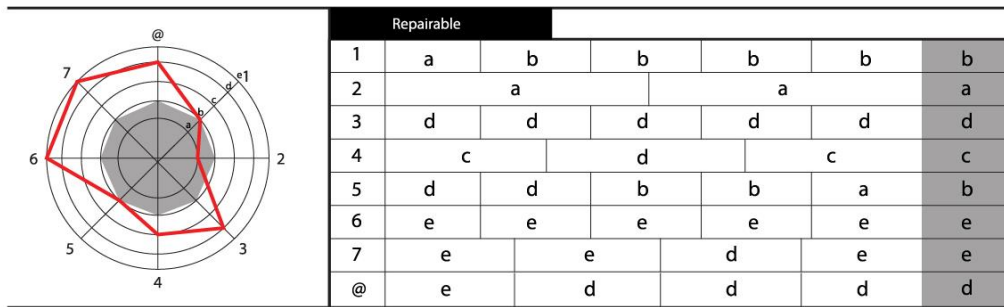
D. About realization and developing cost

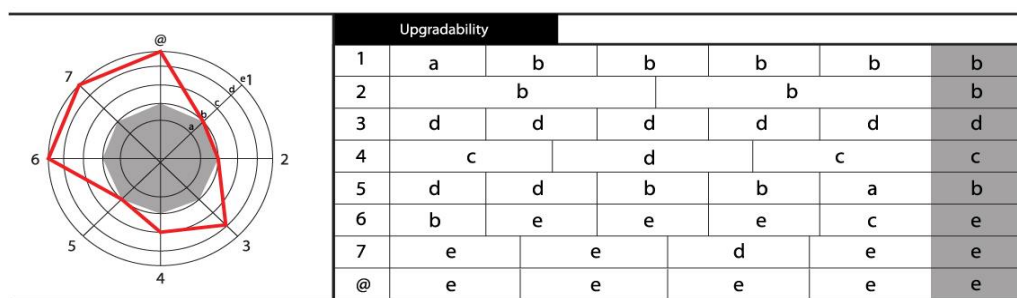
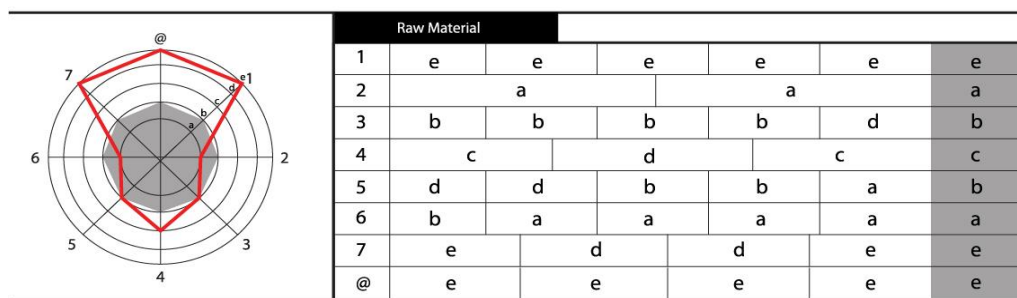
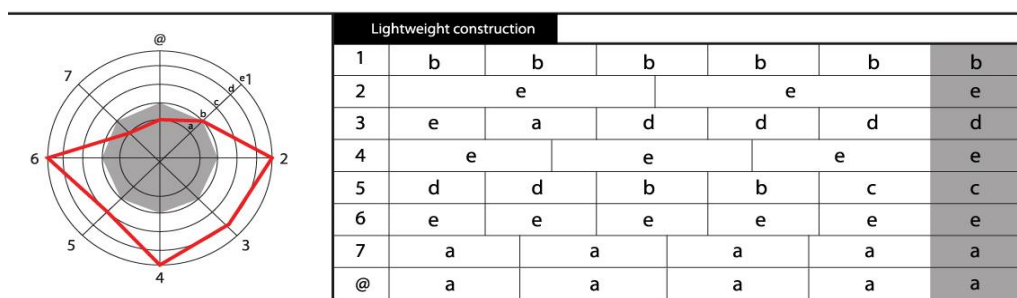
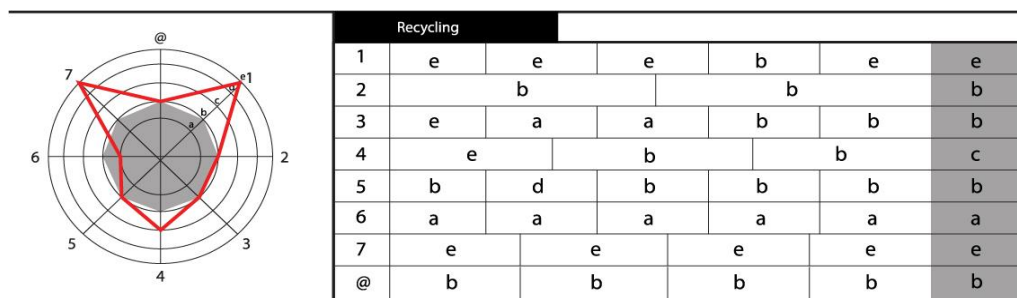
- To do realization of eco designed product has not usual project in Korea then if company do eco designed product development, is it possible to make economical profit?

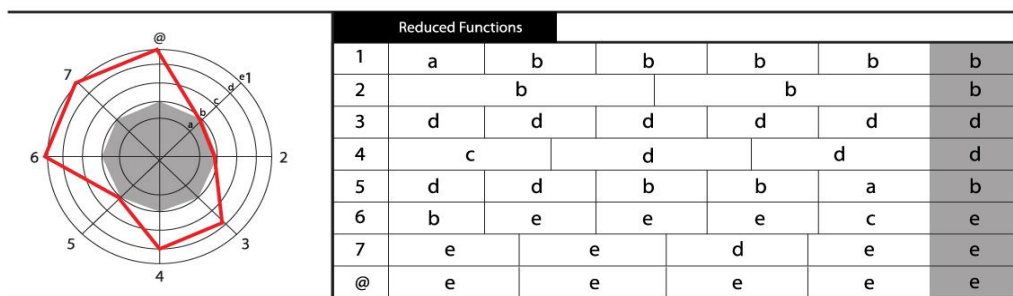
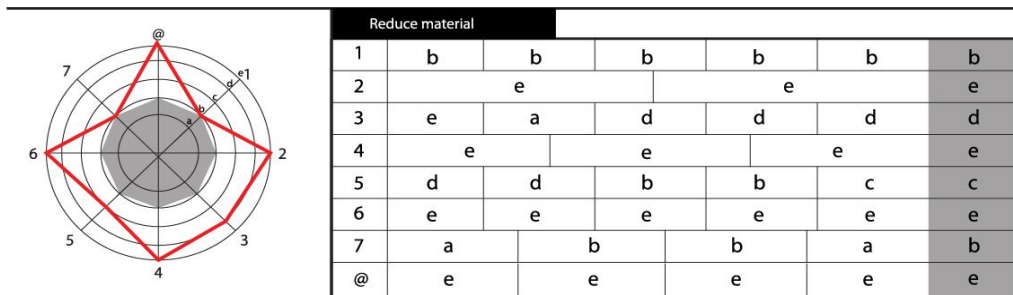
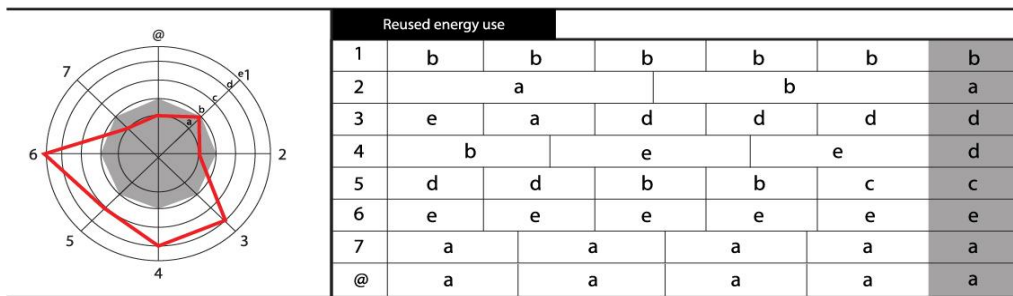
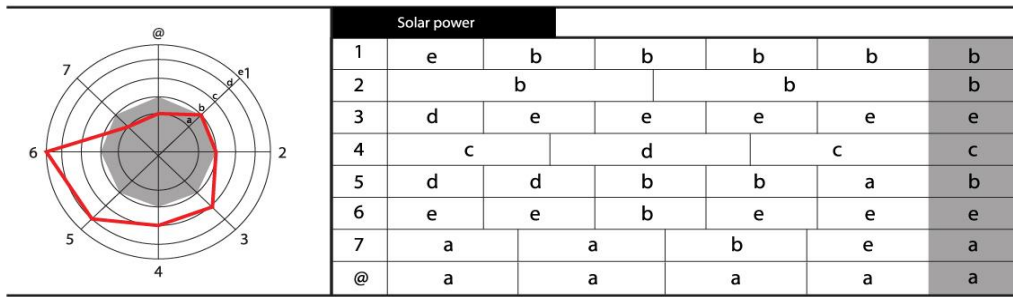
Appendix_3. Applying Eco design strategy wheel to eco design tools











Appendix_4. Mobile phone inventory lists (Existed mobile phone)

Name of effects	Weighted result
Korea Ministry of Industry & Energy_ADP	3.32E-05
Korea Ministry of Industry & Energy _AP	1.65E-06
Korea Ministry of Industry & Energy _EP	1.59E-06
Korea Ministry of Industry & Energy _GWP	3.15E-05
Korea Ministry of Industry & Energy _HTP	1.08E-05
Korea Ministry of Industry & Energy _ODP	1.99E-07
Korea Ministry of Industry & Energy _POCP	2.57E-06
Korea Ministry of Industry & Energy _TETP	1.64E-05

Direction	Data categories	Environment	Name of Resource	Unit	Factors
1/yr					Total
INPUT	Resource	Soil	Baryte (BaSO ₄)	kg	3.83E-04
INPUT	Resource	Soil	Bauxite (Al ₂ O ₃)	kg	5.01E-05
INPUT	Resource	Soil	Boron (B)	kg	2.38E-04
INPUT	Resource	Soil	Chromium (Cr)	kg	3.71E-05
INPUT	Resource	Soil	Cobalt (Co)	kg	6.57E-05
INPUT	Resource	Soil	Copper (Cu)	kg	3.60E-04
INPUT	Resource	Soil	Crude oil	kg	2.30E-04
INPUT	Resource	Soil	Diatomite	kg	2.19E-05
INPUT	Resource	Soil	Fluorspar (CaF ₂)	kg	1.91E-04
INPUT	Resource	Soil	Graphite	kg	3.53E-04
INPUT	Resource	Soil	Hard coal	kg	4.28E-05
INPUT	Resource	Soil	Iron ore	kg	7.02E-05
INPUT	Resource	Soil	Lead (Pb)	kg	0.000449
INPUT	Resource	Soil	Manganese (Mn)	kg	1.02E-04
INPUT	Resource	Soil	Molybdenum (Mo)	kg	2.18E-04
INPUT	Resource	Soil	Natural gas	kg	1.55E-04
INPUT	Resource	Soil	Nickel (Ni)	kg	2.37E-04
INPUT	Resource	Soil	Peat	kg	4.89E-05
INPUT	Resource	Soil	Platinum (Pt)	kg	2.03E-05
INPUT	Resource	Soil	Potassium chloride (KCl)	kg	2.79E-05
INPUT	Resource	Soil	Rhenium (Re)	kg	0.000105
INPUT	Resource	Soil	Asbestos	kg	8.81E-05
INPUT	Resource	Soil	Silver (Ag)	kg	3.88E-04
INPUT	Resource	Soil	Sodium (Na)	kg	8.07E-06
INPUT	Resource	Soil	Sodium carbonate (Na ₂ CO ₃)	kg	4.14E-05
INPUT	Resource	Soil	Sulfur (S)	kg	3.79E-04
INPUT	Resource	Soil	Tin (Sn)	kg	2.30E-04
INPUT	Resource	Soil	Zinc (Zn)	kg	4.26E-04

Table appendix 4.1 The analysis of resource from the mobile phone

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg SO2-eq/kg					Total
OUTPUT	Emission	Air	Ammonia (NH3)	kg	0.001701
OUTPUT	Emission	Air	Hydrogen chloride (HCl)	kg	0.000796
OUTPUT	Emission	Air	Hydrogen fluoride (HF)	kg	0.001447
OUTPUT	Emission	Air	Hydrogen sulfide (H2S)	kg	0.001701
OUTPUT	Emission	Air	Nitric acid (HNO3)	kg	0.000461
OUTPUT	Emission	Air	Nitrogen dioxide (NO2)	kg	0.000633
OUTPUT	Emission	Air	Nitrogen oxides (NOx)	kg	0.000633
OUTPUT	Emission	Air	Sulfur dioxide (SO2)	kg	0.000905
OUTPUT	Emission	Air	Sulfuric acid (H2SO4)	kg	0.000588
OUTPUT	Emission	Water	Sulfuric acid (H2SO4)	kg	0.000588
OUTPUT	Emission	Water	Hydrogen chloride (HCl)	kg	0.000796
OUTPUT	Emission	Water	Hydrogen fluoride (HF)	kg	0.001447
OUTPUT	Emission	Water	Hydrogen sulfide (H2S)	kg	0.001701
OUTPUT	Emission	Water	Nitric acid (HNO3)	kg	0.000461

Table appendix 4.2 Ozone Depletion Potential: ODP

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg PO43- - eq/kg					Total
OUTPUT	Emission	Air	Ammonia (NH3)	kg	0.001015
OUTPUT	Emission	Air	Nitrate (NO3-)	kg	0.00029
OUTPUT	Emission	Air	Nitrogen dioxide (NO2)	kg	0.000377
OUTPUT	Emission	Air	Nitrogen oxides (NOx)	kg	0.000377
OUTPUT	Emission	Air	Nitrogenous matter	kg	0.001218
OUTPUT	Emission	Water	Ammonia (NH3)	kg	0.001015
OUTPUT	Emission	Water	COD	kg	6.38E-05
OUTPUT	Emission	Water	Nitrate (NO3-)	kg	0.00029
OUTPUT	Emission	Water	Nitric acid (HNO3)	kg	0.00029
OUTPUT	Emission	Water	Nitrogenous matter	kg	0.001218
OUTPUT	Emission	Water	Phosphorous matter	kg	0.008876
OUTPUT	Emission	Water	Phosphate (PO43-)	kg	0.002901

Table appendix 4.3 Eutrophication: EP

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg CO2-eq/kg					Total
OUTPUT	Emission	Air	Carbon dioxide (CO2)	kg	5.21E-05
OUTPUT	Emission	Air	CFC-11	kg	0.208318
OUTPUT	Emission	Air	CFC-114	kg	0.48434
OUTPUT	Emission	Air	CFC-12	kg	0.442676
OUTPUT	Emission	Air	CFC-13	kg	0.609331
OUTPUT	Emission	Air	Dichloromethane	kg	0.000469

OUTPUT	Emission	Air	Halon-1301	kg	0.291646
OUTPUT	Emission	Air	HCFC-22	kg	0.088535
OUTPUT	Emission	Air	Methane	kg	0.001094
OUTPUT	Emission	Air	Nitrous oxide(N2O)	kg	0.016145
OUTPUT	Emission	Air	Perfluoroethane (C2F6)	kg	0.479132
OUTPUT	Emission	Air	Perfluoromethane (CF4)	kg	0.338517
OUTPUT	Emission	Air	Sulfur hexafluoride (SF6)	kg	1.244702
OUTPUT	Emission	Air	Dichloromethane (CHCl3)	kg	0.00026

Table appendix 4.5 global warming: GWP

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg 1,4 DCB eq./kg					Total
OUTPUT	Emission	Air	1,2-dichloroethane	kg	4.83E-04
OUTPUT	Emission	Air	1,3-butadiene	kg	0.157812
OUTPUT	Emission	Air	Acrolein	kg	4.04E-03
OUTPUT	Emission	Air	Acrylonitrile	kg	0.237753
OUTPUT	Emission	Air	Antimony (Sb)	kg	0.475873
OUTPUT	Emission	Air	Arsenic (As)	kg	24.66789
OUTPUT	Emission	Air	Barium (Ba)	kg	5.37E-02
OUTPUT	Emission	Air	Benzene	kg	0.134791
OUTPUT	Emission	Air	Beryllium (Be)	kg	16.07854
OUTPUT	Emission	Air	Carbon disulfide(CS2)	kg	1.71E-04
OUTPUT	Emission	Air	Chromium3+(Cr3+)	kg	4.59E-02
OUTPUT	Emission	Air	Chromium4+(Cr4+)	kg	243.0133
OUTPUT	Emission	Air	Cobalt (Co)	kg	1.239442
OUTPUT	Emission	Air	Dichloromethane	kg	1.40E-04
OUTPUT	Emission	Air	Dioxins (TCDD)	kg	137208.2
OUTPUT	Emission	Air	Dust	kg	5.82E-05
OUTPUT	Emission	Air	Ethyl benzene	kg	6.90E-05
OUTPUT	Emission	Air	Ethylene	kg	4.52E-05
OUTPUT	Emission	Air	Ethylene oxide	kg	0.998538
OUTPUT	Emission	Air	Formaldehyde	kg	5.89E-05
OUTPUT	Emission	Air	Hexa chlorobenzene	kg	223.9837
OUTPUT	Emission	Air	Hydrogen chloride (HCl)	kg	3.55E-05
OUTPUT	Emission	Air	Hydrogen fluoride (HF)	kg	0.20224
OUTPUT	Emission	Air	Hydrogen sulfide (H2S)	kg	1.56E-05
OUTPUT	Emission	Air	Molybdenum (Mo)	kg	0.384973
OUTPUT	Emission	Air	Naphthalene	kg	5.75E-04
OUTPUT	Emission	Air	Nickel (Ni)	kg	2.485438
OUTPUT	Emission	Air	Nitrogen dioxide	kg	8.51E-05

			(NO2)		
OUTPUT	Emission	Air	PAHs	kg	40.60944
OUTPUT	Emission	Air	Penta chlorobenzene	kg	2.91E-02
OUTPUT	Emission	Air	Pentachlorophenol	kg	3.60E-04
OUTPUT	Emission	Air	Phenol	kg	3.68E-05
OUTPUT	Emission	Air	Propylene oxide	kg	8.96E-02
OUTPUT	Emission	Air	Selenium (Se)	kg	3.38321
OUTPUT	Emission	Air	Styrene	kg	3.36E-06
OUTPUT	Emission	Air	Sulfur dioxide(SO2)	kg	6.81E-06
OUTPUT	Emission	Air	Thallium (Tl)	kg	30.66215
OUTPUT	Emission	Air	Tin (Sn)	kg	1.23E-04
OUTPUT	Emission	Air	Toluene	kg	2.32E-05
OUTPUT	Emission	Air	Trichloromethane (CHCl3)	kg	8.98E-04
OUTPUT	Emission	Air	Vanadium (V)	kg	0.442728
OUTPUT	Emission	Air	Vinyl chloride	kg	5.98E-03
OUTPUT	Emission	Water	1,2-dichloroethane	kg	1.98E-03
OUTPUT	Emission	Water	Antimony (Sb)	kg	0.364767
OUTPUT	Emission	Water	Chlorobenzene	kg	6.46E-04
OUTPUT	Emission	Water	Chromium3+ (Cr3+)	kg	1.46E-04
OUTPUT	Emission	Water	Cobalt (Co)	kg	6.86E-03
OUTPUT	Emission	Water	Copper++(Cu++)	kg	4.19E-04
OUTPUT	Emission	Water	Dichloromethane	kg	2.12E-05
OUTPUT	Emission	Water	Lead++(Pb++)	kg	5.59E-03
OUTPUT	Emission	Water	Mercury++(Hg++)	kg	0.101166
OUTPUT	Emission	Water	Molybdenum (Mo)	kg	0.481648
OUTPUT	Emission	Water	Nickel (Ni)	kg	2.35E-02
OUTPUT	Emission	Water	Tetrachloroethylene	kg	4.06E-04
OUTPUT	Emission	Water	Thallium (Tl)	kg	20.88248
OUTPUT	Emission	Water	Tin (Sn)	kg	1.23E-06
OUTPUT	Emission	Water	Toluene	kg	2.15E-05
OUTPUT	Emission	Soil	Cobalt (Co)	kg	0.169237
OUTPUT	Emission	Soil	Nickel (Ni)	kg	0.190053
OUTPUT	Emission	Water	Arsenic (As)	kg	6.74E-02
OUTPUT	Emission	Water	Barium (Ba)	kg	4.47E-02
OUTPUT	Emission	Water	Benzene	kg	0.014891
OUTPUT	Emission	Water	Beryllium (Be)	kg	0.991451
OUTPUT	Emission	Water	Cadmium++ (Cd++)	kg	7.37E-03
OUTPUT	Emission	Water	Ethyl benzene	kg	4.98E-06
OUTPUT	Emission	Water	Formaldehyde	kg	2.63E-06
OUTPUT	Emission	Water	Hydrogen fluoride (HF)	kg	0.258207
OUTPUT	Emission	Water	PAHs	kg	19.89812
OUTPUT	Emission	Water	Phenol	kg	5.65E-09
OUTPUT	Emission	Water	Selenium (Se)	kg	3.97375
OUTPUT	Emission	Water	Trichloroethylene	kg	1.00E-03
OUTPUT	Emission	Water	Trichloromethane	kg	8.89E-04

			(CHCl ₃)		
OUTPUT	Emission	Water	Vanadium (V)	kg	0.442271
OUTPUT	Emission	Water	Vinyl chloride	kg	3.02E-03
OUTPUT	Emission	Water	Zinc++ (Zn++)	kg	2.27E-04
OUTPUT	Emission	Soil	Arsenic (As)	kg	2.257006

Table appendix 4.7 human toxicity: HTP

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg CFC 11-eq/kg					Total
OUTPUT	Emission	Air	CFC-11	kg	7.174447
OUTPUT	Emission	Air	CFC-114	kg	7.174447
OUTPUT	Emission	Air	CFC-12	kg	7.174447
OUTPUT	Emission	Air	CFC-13	kg	7.174447
OUTPUT	Emission	Air	HCFC-21	kg	0.286978
OUTPUT	Emission	Air	Halon-1211	kg	21.52334
OUTPUT	Emission	Air	Halon-1301	kg	71.74447
OUTPUT	Emission	Air	HCFC-22	kg	0.394595

Table appendix 4.8 ozone layer destruction: ODP

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg ethylene eq./kg					Total
OUTPUT	Emission	Air	1,3-butadiene	kg	0.00537
OUTPUT	Emission	Air	Acetaldehyde	kg	0.004045
OUTPUT	Emission	Air	Acetic acid	kg	0.000612
OUTPUT	Emission	Air	Acetone	kg	0.000593
OUTPUT	Emission	Air	Acetylene	kg	0.000536
OUTPUT	Emission	Air	Benz aldehyde	kg	-0.00058
OUTPUT	Emission	Air	Benzene	kg	0.001376
OUTPUT	Emission	Air	But-1-ene	kg	0.006809
OUTPUT	Emission	Air	Carbon monoxide (CO)	kg	0.00017
OUTPUT	Emission	Air	Dichloromethane	kg	0.000429
OUTPUT	Emission	Air	Ethane	kg	0.000776
OUTPUT	Emission	Air	Ethanol	kg	0.002518
OUTPUT	Emission	Air	Ethyl benzene	kg	0.004607
OUTPUT	Emission	Air	Ethylene	kg	0.006311
OUTPUT	Emission	Air	Formaldehyde	kg	0.003275
OUTPUT	Emission	Air	Hydrocarbons	kg	0.002127
OUTPUT	Emission	Air	I-propyl benzene	kg	0.003155
OUTPUT	Emission	Air	Methane	kg	3.79E-05
OUTPUT	Emission	Air	Methanol	kg	0.000883
OUTPUT	Emission	Air	Methyl chloride	kg	3.16E-05

OUTPUT	Emission	Air	Methyl-t-butyl ether	kg	0.001104
OUTPUT	Emission	Air	N-butane	kg	0.002221
OUTPUT	Emission	Air	N-heptane	kg	0.003117
OUTPUT	Emission	Air	N-hexane	kg	0.003042
OUTPUT	Emission	Air	Nitrogen dioxide (NO2)	kg	0.000177
OUTPUT	Emission	Air	NM VOC	kg	0.002625
OUTPUT	Emission	Air	N-pentane	kg	0.002493
OUTPUT	Emission	Air	Propane	kg	0.001111
OUTPUT	Emission	Air	Propionaldehyde	kg	0.005036
OUTPUT	Emission	Air	Styrene	kg	0.000896
OUTPUT	Emission	Air	Sulfur dioxide (SO2)	kg	0.000303
OUTPUT	Emission	Air	T-butyl acetate	kg	0.000334
OUTPUT	Emission	Air	Toluene	kg	0.00402
OUTPUT	Emission	Air	Trichloromethane (CHCl3)	kg	0.000145

Table appendix 4.9 photochemical oxidant creation: POCP

Direction	Data categories	Environment	Name of Resource	Unit	Factors
kg 1,4 DCB eq./kg					Total
OUTPUT	Emission	Air	1,2-dichloroethane	kg	3.50E-06
OUTPUT	Emission	Air	1,3-butadiene	kg	3.08E-09
OUTPUT	Emission	Air	Acrolein	kg	2.163858
OUTPUT	Emission	Air	Acrylonitrile	kg	1.06E-03
OUTPUT	Emission	Air	Antimony (Sb)	kg	8.09E-02
OUTPUT	Emission	Air	Arsenic (As)	kg	213.2305
OUTPUT	Emission	Air	Barium (Ba)	kg	0.643993
OUTPUT	Emission	Air	Benzene	kg	2.06E-06
OUTPUT	Emission	Air	Benzo[a]pyrene	kg	3.20E-02
OUTPUT	Emission	Air	Beryllium (Be)	kg	234.1495
OUTPUT	Emission	Air	Carbon disulfide (CS2)	kg	6.82E-04
OUTPUT	Emission	Air	Chromium3+ (Cr3+)	kg	401.6697
OUTPUT	Emission	Air	Chromium4+(Cr4+)	kg	401.6697
OUTPUT	Emission	Air	Cobalt (Co)	kg	14.4057
OUTPUT	Emission	Air	Dioxins (TCDD)	kg	1589.069
OUTPUT	Emission	Air	Ethyl benzene	kg	1.90E-07
OUTPUT	Emission	Air	Ethylene	kg	1.79E-13
OUTPUT	Emission	Air	Ethylene oxide	kg	3.34E-04
OUTPUT	Emission	Air	Formaldehyde	kg	0.124531
OUTPUT	Emission	Air	Hexachlorobenzene	kg	3.45E-02
OUTPUT	Emission	Air	Hydrogen fluoride (HF)	kg	3.91E-04
OUTPUT	Emission	Air	Molybdenum (Mo)	kg	2.32407
OUTPUT	Emission	Air	Naphthalene	kg	1.09E-04
OUTPUT	Emission	Air	PAHs	kg	0.148486

OUTPUT	Emission	Air	Pentachlorobenzene	kg	5.19E-03
OUTPUT	Emission	Air	Pentachlorophenol	kg	0.298532
OUTPUT	Emission	Air	Phenol	kg	4.39E-04
OUTPUT	Emission	Air	Propylene oxide	kg	7.09E-08
OUTPUT	Emission	Air	Selenium (Se)	kg	7.085987
OUTPUT	Emission	Air	Styrene	kg	1.80E-08
OUTPUT	Emission	Air	Thallium (Tl)	kg	45.03299
OUTPUT	Emission	Air	Tin (Sn)	kg	1.903452
OUTPUT	Emission	Air	Toluene	kg	2.11E-06
OUTPUT	Emission	Air	Trichloromethane (CHCl3)	kg	5.33E-06
OUTPUT	Emission	Air	Vanadium (V)	kg	3.46E-08
OUTPUT	Emission	Water	1,2-dichloroethane	kg	3.47E-06
OUTPUT	Emission	Water	Antimony (Sb)	kg	3.92E-21
OUTPUT	Emission	Water	Chlorobenzene	kg	9.49E-05
OUTPUT	Emission	Water	Chromium3+(Cr3+)	kg	2.72E-19
OUTPUT	Emission	Water	Cobalt (Co)	kg	3.57E-19
OUTPUT	Emission	Water	Copper++ (Cu++)	kg	5.38E-22
OUTPUT	Emission	Water	Dichloromethane	kg	5.16E-07
OUTPUT	Emission	Water	Lead++(Pb++)	kg	6.05E-22
OUTPUT	Emission	Water	Mercury++(Hg++)	kg	123.2827
OUTPUT	Emission	Water	Molybdenum (Mo)	kg	3.06E-19
OUTPUT	Emission	Water	Nickel (Ni)	kg	1.36E-19
OUTPUT	Emission	Water	tetrachloroethylene	kg	5.31E-04
OUTPUT	Emission	Water	Thallium (Tl)	kg	5.54E-18
OUTPUT	Emission	Water	Tin (Sn)	kg	1.04E-22
OUTPUT	Emission	Water	Toluene	kg	1.88E-06
OUTPUT	Emission	Soil	Cobalt (Co)	kg	29.55212
OUTPUT	Emission	Soil	Nickel (Ni)	kg	31.61178
OUTPUT	Emission	Water	Arsenic (As)	kg	3.92E-18
OUTPUT	Emission	Water	Barium (Ba)	kg	8.77E-20
OUTPUT	Emission	Water	Benzene	kg	2.27E-07
OUTPUT	Emission	Water	Beryllium (Be)	kg	4.37E-17
OUTPUT	Emission	Water	Cadmium++(Cd++)	kg	1.88E-21
OUTPUT	Emission	Water	Ethyl benzene	kg	1.57E-07
OUTPUT	Emission	Water	Formaldehyde	kg	3.21E-06
OUTPUT	Emission	Water	Hydrogen fluoride (HF)	kg	6.03E-06
OUTPUT	Emission	Water	PAHs	kg	2.81E-04
OUTPUT	Emission	Water	Phenol	kg	3.30E-07
OUTPUT	Emission	Water	Selenium (Se)	kg	2.33E-18
OUTPUT	Emission	Water	Trichloroethylene	kg	2.58E-07
OUTPUT	Emission	Water	Trichloromethane (CHCl3)	kg	5.20E-06
OUTPUT	Emission	Water	Vanadium (V)	kg	2.87E-18
OUTPUT	Emission	Water	Vinyl chloride	kg	3.39E-08
OUTPUT	Emission	Water	Zinc++(Zn++)	kg	2.58E-21

OUTPUT	Emission	Soil	Arsenic (As)	kg	442.0278
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Table appendix 4.9 resources exhaustion: TERP

Appendix 5. Applying Eco design Method to mobile phone case

This research has been undertaken with Su -Won University eco research LAB. The research tested eight different types of Eco design methods; DFD, Durability, Upgradable, Recycling, Energy Saving, Anti-Fashion, Reduced material and Material Reduction. The author and an LCA expert considered weightings for each different method's features and compared this with a mobile phone case.

(1) LCA result of raw material exhaustion.

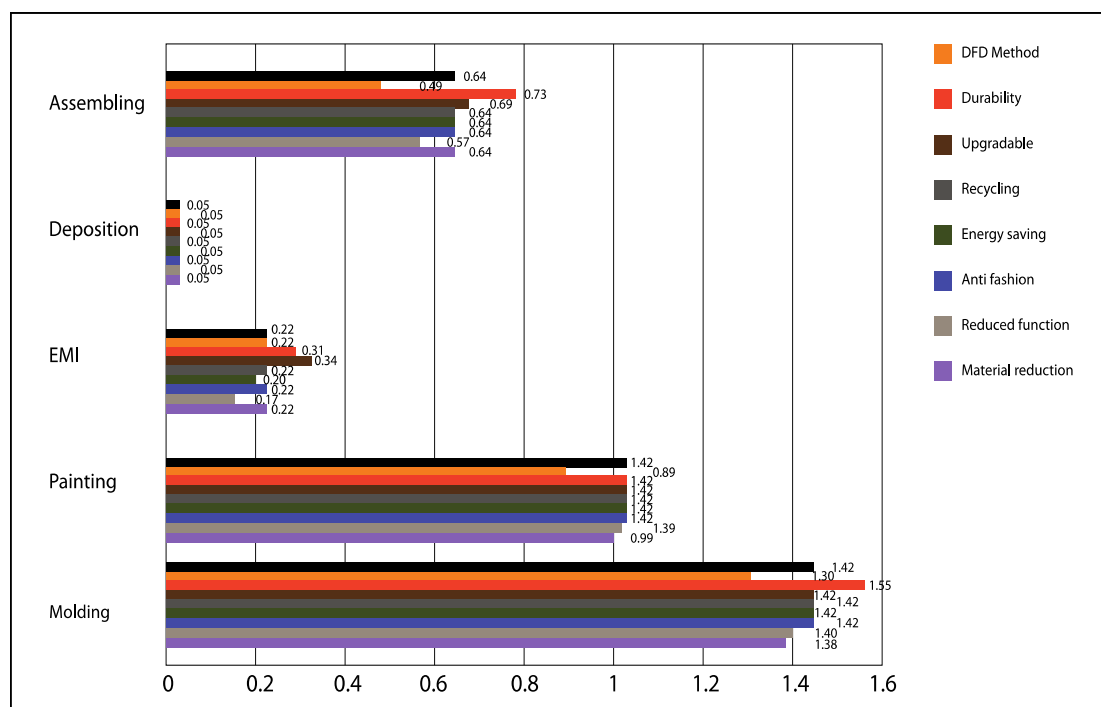


Figure appendix 6.1 LCA result natural resources exhaustion

This graph illustrates that each tool impacts natural resources. The largest impact to natural resources is in the moulding process, however the DFD method reduced by 0.12 points (Per g). The DFD method also shows strong impact on painting and assembly processes. The durability method is the weakest for moulding, EMI and particularly the assembly process. The durability method is only focused on extending product lifespan. Other methods show almost the same impact as normal mobile phones in this graph.

(2) LCA result of the global warming

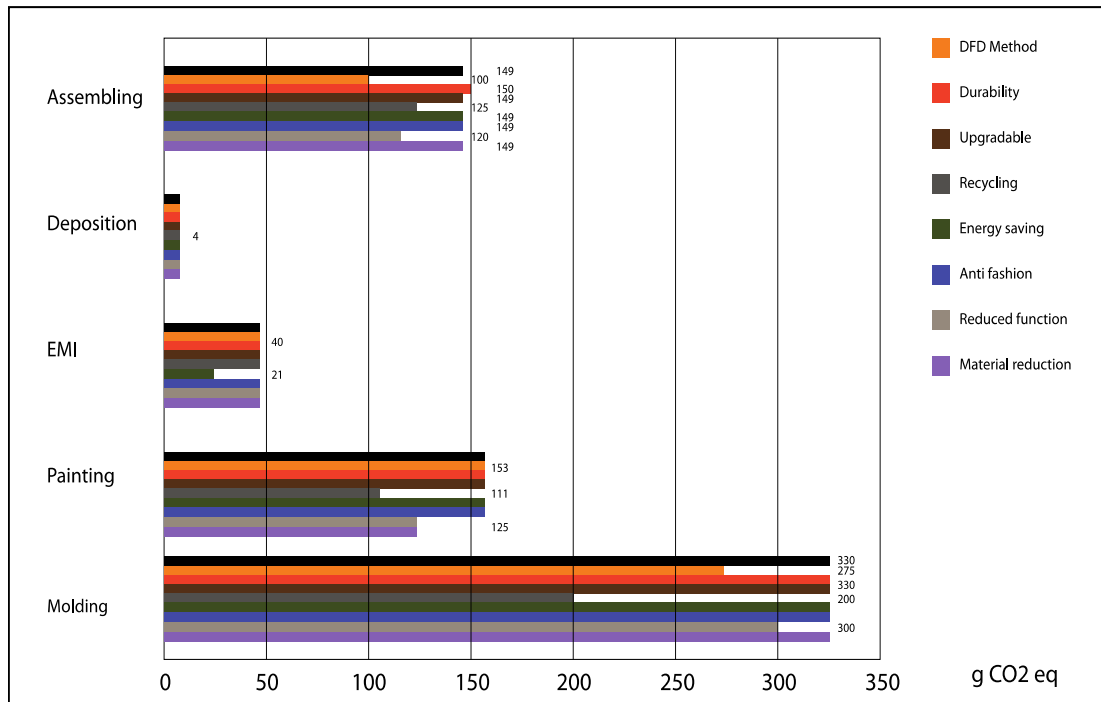


Figure appendix 6.2 LCA result of the global warming

In this graph each eco design method has impacted global warming directly and indirectly. When using the DFD method in the assembly process instead of the general design process, global warming can be reduced by 49 gram of CO₂.

The recycling design method shows outstanding result for the moulding process. Compared with using general design methods or other eco design methods, the recycling design method succeeds in reducing by 130 gram of CO₂ emission. It means recycling design method is the most effective design method for reducing global warming.

(3) LCA result of the Ozone layer destruction

This graph shows a comparison of eco design methods with each manufacturing process impact on the Ozone layer.

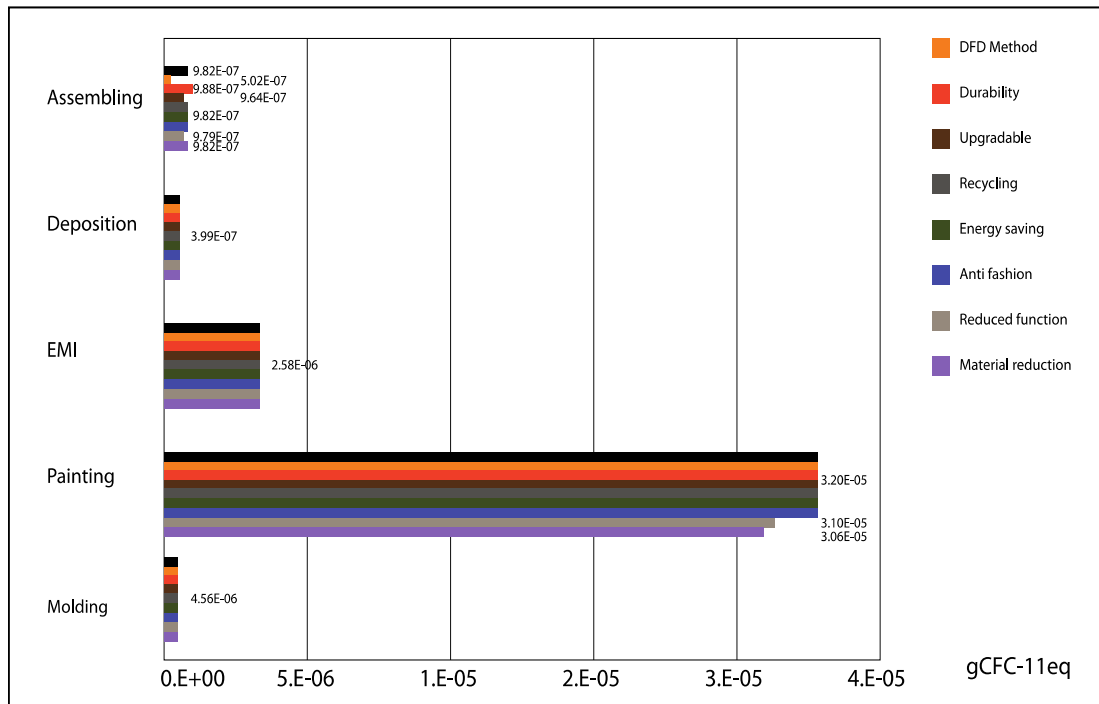


Figure appendix 6.3 LCA result of ozone layer destruction

Most results show the same outcome however the DFD method worked in the assembly process more effectively and material reduction followed. Reduction function and Material Reduction give less impact on global warming in the painting process.

The ozone layer is impacted by emissions of materials such as CO₂, waste water and other chemical materials however, almost all eco design methods do not include the manufacturing process especially the amount of materials used and emissions. Therefore this graph shows similar results.

(4) LCA result of the photochemical oxidant creation

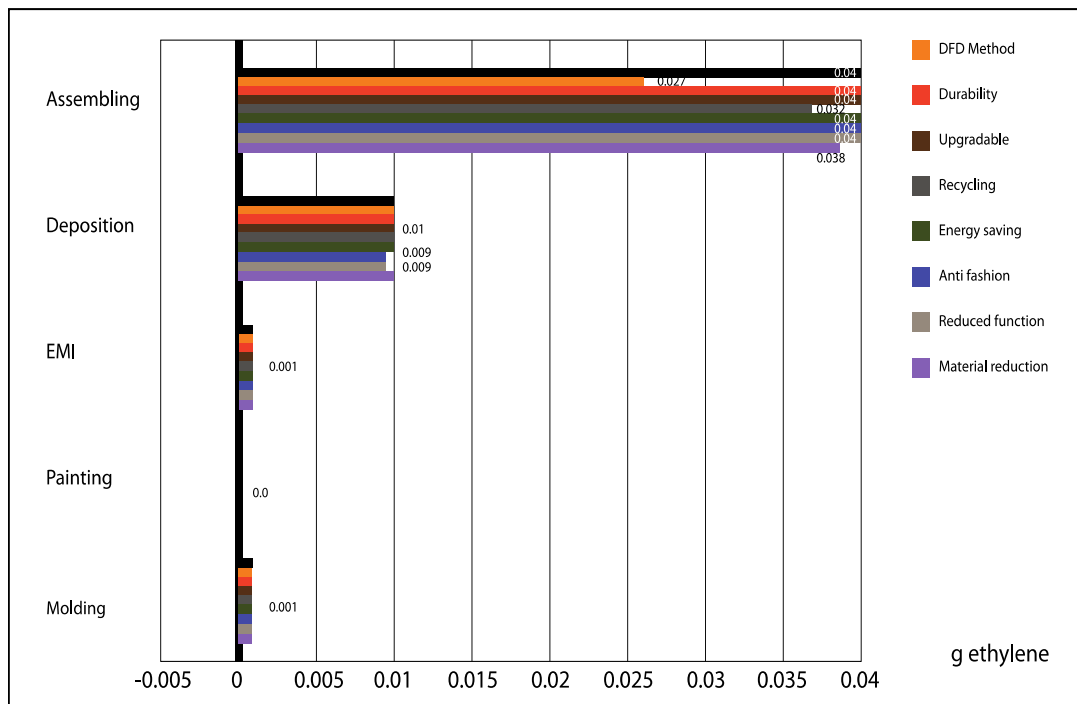


Figure appendix 6.4 LCA result of the photochemical oxidant creation

Photochemical oxidant creation is known to produce city smoke. Photochemical oxidant means when material meets sun light with O₂ then characteristics of materials chemical changes. Most Photochemical oxidants are created in the assembly process. The DFD design method reduces ethylene by 0.013grams. However all eco design methods created the same amount of this in other manufacturing processes such as deposition, EMI, painting and the moulding process.

(5) LCA result of the acidification

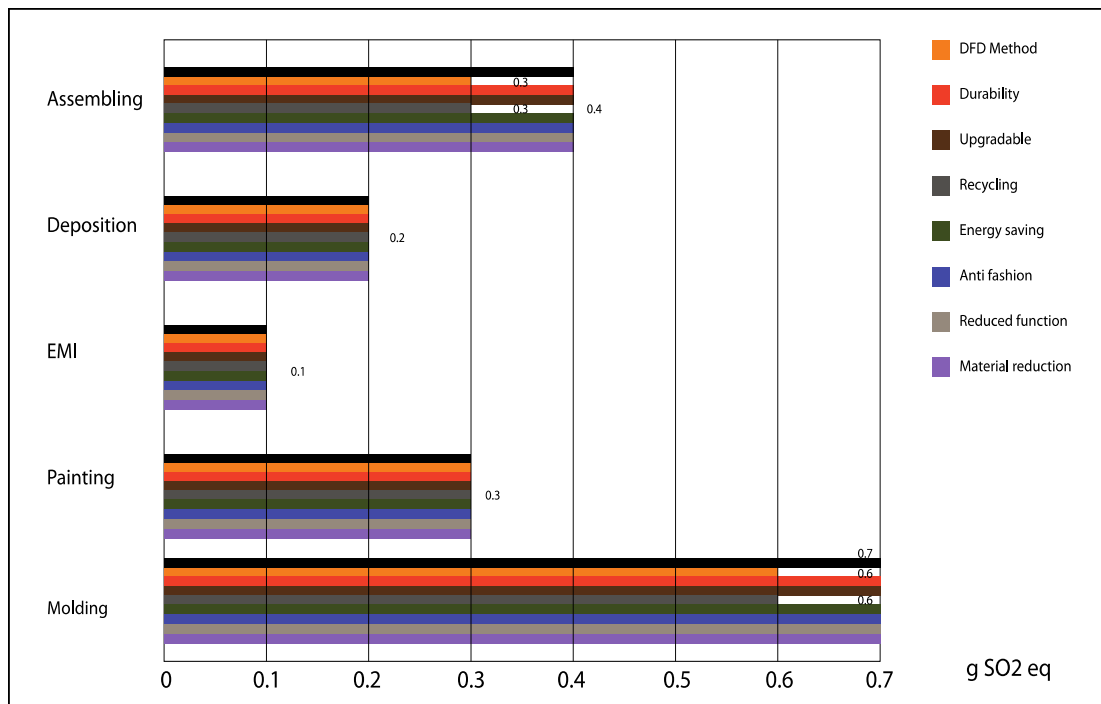


Figure appendix 6.5 LCA result of the acidification

DFD and the recycling design method work more effectively than other design tools. Manufacturing mobile phones included a 39% potential eco impact, however the amount of acidification is very small compared with other categories. As a result of control modelling (using general design methods), the moulding process shows the highest eco impact in acidification because the moulding process demanded 56% of the electrical supply during the whole manufacturing process.

(6) LCA result of the eutrophication

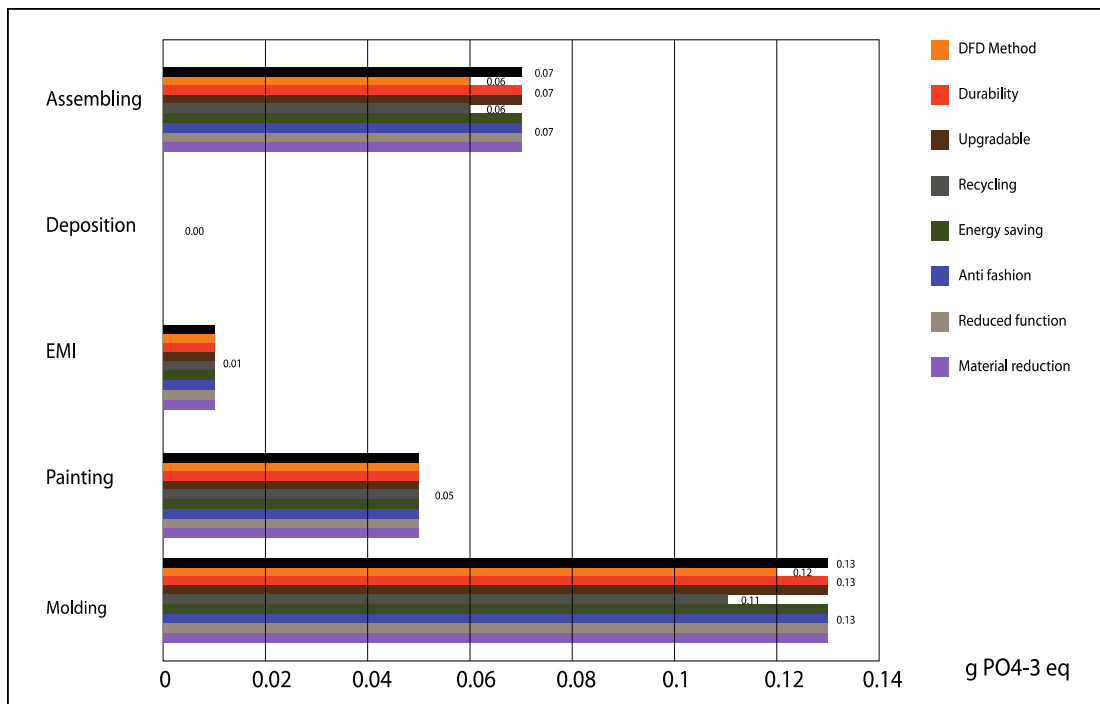


Figure appendix 6.6 LCA result of the eutrophication

The eutrophication is influenced by Nitrogen Oxide(NOx). Most NOx is emitted from the moulding and assembly process. The DFD and recycling methods emitted less NOx and the recycling design method was the most effective tool for moulding because recycling needs less shipping and processed raw material steps.

The DFD design method is also shown as having less impact in the moulding process because the DFD method has a reduction in manufacturing processes and product components.

(7) LCA results of human toxicity

These results show that the recycling design method reduces human toxicity in the assembly process. The reason is that the recycling method considers potential capability, which means post product usage evaluation.

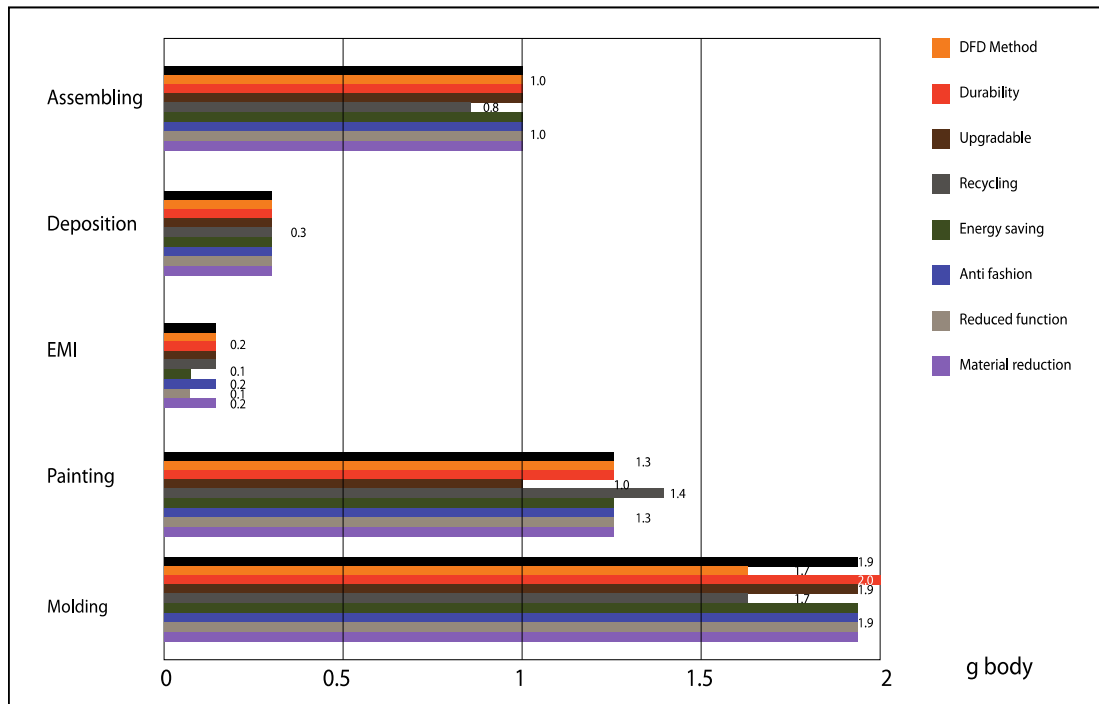


Figure appendix 6.7 LCA results of human toxicity

Energy saving and reduced function gives less impact to humans in the EMI process. The moulding process impacts humans mostly. The Durability design process also gives more impact than general designed products. The DFD design method and energy saving can reduce impact effectively.