GREENING OPERATIONS: AN INVESTIGATION OF ENVIRONMENTAL DECISION MAKING

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Thesis Abstract

This PhD thesis belongs to three main knowledge domains: operations management, environmental management, and decision making. Having the automotive industry as the key sector, the investigation was undertaken aiming at deepening the understanding of environmental decision making processes in the operations function. The central research question for this thesis is "Why and how do manufacturing companies take environmental decisions?"

This PhD research project used a case study research strategy supplemented by secondary data analysis and the testing and evaluation of a proposed systems thinking model for environmental decision making. Interviews and focus groups were the main methods for data collection.

The findings of the thesis show that companies that want to be in the environmental leadership will need to take environmental decisions beyond manufacturing processes. Because the benefits (including financial gain) of non-manufacturing activities are not clear yet the decisions related to product design, supply chain and facilities are fully embedded with complexity, subjectivism, and intrinsic risk. Nevertheless, this is the challenge environmental leaders will face - they may enter in a paradoxical state of their decisions – where although the risk of going greener is high, the risk of not doing it is even higher.

Keywords: green operations, automotive industry, environmental decision making, systems thinking, environmental strategy and management.

Executive Summary

Greening Operations:
An investigation of environmental decision making

This PhD thesis reports an investigation of green operations initiatives and environmental decision making. It includes the analysis of the drivers for environmental initiatives, origin of ideas, decision making processes as well as the development, application, and evaluation of a systems thinking environmental decision making approach developed by the author.

Four research questions (RQ) were considered in this study:

- *RQ1: In what way does the context play a role in the environmental decisions of companies?*
- *RQ2: What are the drivers for manufacturing companies to take environmental decisions?*
- *RQ3: Where do (environmental) solutions come from?*
- *RQ4: How does a structured approach contribute to effectively improve environmental decisions?*

Due to the nature of the above research questions, the research methodology is predominantly qualitative. Qualitative research will allow us to look in more detail at the reasons behind environmental initiatives as well as the driver for a particular decision and its sources of ideas. The research strategy employed was case study, which accommodated the necessity of dealing with contemporary, complex and contextualised phenomena in environmental decision making within the operations function.

Three distinct phases were established in this research project: (a) diagnosis and evaluation of green operations initiatives; (b) identification of drivers, origin of ideas, and environmental decision making processes; and (c) systems environmental decision making methodology - development, application and evaluation.

In phase (a), we used two main methods – secondary data analysis and personal interviews. Environmental reports from automotive companies were analysed to be compared to the existing literature in green operations. As a result, we developed a set of 5 green operations practices: green buildings, eco design, green supply chains, green manufacturing, and reverse logistics. We have also considered innovation as a possible way to improve environmental performance of production systems. In addition to secondary data analysis, an additional case study examined the issues of environmental decision making and green technology transfer in the automotive industry.

Data related to the drivers for environmental decisions, origin of ideas and environmental decision making processes were collected through personal interviews and a focus group activity in Phase (b). Interviewees were mainly environmental managers or people with relevant participation in environmental decisions. In some

firms/companies, it was possible to have further access and interview other employees such as communication managers, managing directors, managing director assistant, amongst others, in order to verify the impact of environmental decisions in the case company. Interviews varied in length; but they usually took between one and two hours. In one of the cases, a focus group was used to collect data; nevertheless, the structure of the focus group was based upon the semi-structure questionnaire used in the interviews.

Phase (c) of the research included the test and evaluation of our systems environmental decision making methodology through two focus group activities. There were two participants in the two sessions to use and evaluate the methodology. The participants also responded to a survey for the methodology evaluation.

Six economic segments were involved in the research, namely:

a) Automotive: nine cases,
b) Non-automotive: five cases – carpet, garments, food processing, chemical, and higher education.

The choice of the automotive sector as the main economic segment was given by the context of the industry. Automakers are currently facing economic and environmental challenges. The industry suffers from overcapacity, and is struggling with low profit margins, high break-even points, and undergoing increasing pressure to reduce its environmental burdens. Most of these pressures relate to the consumption of fossil fuels and the consequent engine gas emissions during the car use, intensive use of natural resources of the manufacturing processes, production plant emissions, final disposal of cars, and also, traffic congestion and road accidents. Thus, these economic and environmental problems bring huge complexity for the strategic decisions within the operations function. Furthermore, the automotive industry is one of sectors that employs most people; therefore, there are relevant reasons to conduce scientific research to ensure that better environmental decisions are taken within this industry.

Furthermore, with the current plans to reduce CO_2 emissions globally, it is expected that car manufacturers will suffer a large impact due to the emissions from their production processes, and mainly, from the emissions originated from the car use (tailpipe emissions).

In order to harmonise the data for analysis, this research considered environmental decision making teams (or decision makers) as its unit of analysis. This made it possible to look at distinct operations activities and economic segments and investigate how environmental decision making processes were being carried out in different contexts.

The findings of the thesis show that companies that want to be in the environmental leadership will need to take environmental decisions beyond manufacturing processes. Because the benefits (including financial gain) of non-manufacturing activities are not clear yet the decisions related to product design, supply chain and facilities are fully embedded with complexity, subjectivism, and intrinsic risk. Nevertheless, this is the challenge environmental leaders will face - they may enter in a paradoxical state of their decisions – where although the risk of going greener is high, the risk of not doing it is even higher.

This study contributes to both theory and practice of green operations and environmental decision making. From a theoretical perspective, there are two main contributions. Firstly, it has established a categorisation for green operations practices which improves our understanding of the topic within academic circles. Secondly, the depth of the analysis on the drivers, origin of ideas, and environmental decision making process have brought to knowledge original and generalisable issues with regard to why and how the companies go green. In addition, the link between the green operations practices and the nature of the environmental decisions is unique in the field.

For practice, the contribution starts from the benchmarking of green operations initiatives in the automotive industry. The benchmarking and analysis of green operations initiatives is useful for companies in the automotive sectors as well as for companies in different industries. Due to the maturity and awareness of its environmental impacts, the automotive industry can serve as an example for the green practices and concerns companies should consider when developing their environmental strategies.

Last but not least, this thesis offers a systems model which aims at improving environmental decision making in organisations. Since more and more companies will have to make important decisions in a near future, the model can be understood as both a theoretical and practical contribution. The application and evaluation of the model in a real decision making experiment has brought insights that will also impact the theory and practice of environmental strategies.

Keywords: green operations, automotive industry, environmental decision making, systems thinking, environmental strategy and management.

This PhD thesis is dedicated to Livia and Benjamin Nunes

Published work from this thesis

Working paper

Nunes, B. and Bennett, D.J. and Shaw, D (2011) A systems approach to environmental decision making in operations, *International Journal of Production Research*, (to be submitted to 2nd review).

Refereed Journal Papers

Nunes, B. and Bennett, D.J. (2010) Green Operations Initiatives in the Automotive Industry: An Environmental Reports Analysis and Benchmarking Study, *Benchmarking An International Journal*, Vol 17, No 3, pp 396-420.

Nunes, B. and Bennett, D.J. (2008) The Contribution of Modularity to Green Operations Practices, *Brazilian Journal of Operations and Production Management*, Vol 5, No 2, pp 93-108.

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Four years, five months, and twenty days after leaving from Brazil to start my PhD at Aston University – here I am, finally writing the acknowledgement pages of my thesis before printing it off to final submission.

It was a phenomenal learning experience for me to have carried out my PhD studies in the UK, particularly at Aston Business School (Birmingham). To add more challenge to my journey, I opted to investigate the research questions of my PhD through a qualitative methodology. While the power of qualitative methods is as great as the concerns to make their results legitimate, the breadth of the academic discussions in business school is frightening. For an engineer, these were probably more challenging than getting access to companies during the World's big financial crisis! But in the end, it was enjoyable, interesting, and very instrumental for the development of new research, intellectual (and emotional?) skills - specially those skills required to deal with contemporary management issues!

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Chapter 1 - Introduction

This chapter presents an introduction to this thesis. It begins with a brief introduction about the sustainability of global businesses and the challenges of a sustainable automotive industry. Then, it will inform the research questions, their context, reasons and relevance. The structure of the thesis, its objective and contribution are also presented in this section. This thesis is mostly centred on understanding the environmental decisions and decision making process of car manufacturers; nevertheless, it includes non-automotive sectors as part of the case study research. The methodology is predominantly qualitative and the research strategy used is case study research. Various research methods were employed, namely: secondary data analysis, interviews, and focus group.

1.1 Introduction to Sustainability

Although a recent debate in the discipline of business, sustainability has been discussed for a long time in other academic circles like philosophy, history, sociology, biology and other natural sciences. Philosophers, historians, sociologists, and biologists have analysed the collapse of ecosystems, societies, and economies throughout the time. Besides the military power analysis which include the relationship between allies and enemies, studies on the resilience and collapse of ancient civilizations were usually linked to use, degradation and availability of (natural) resources, strength of social institutions, and individual and collective behaviour. In Economics, for instance, a landmark of sustainability study (although not using the term sustainability) is the Essay on Population by Thomas Malthus (Malthus, 1798). Indeed, Thomas Malthus could not predict both stable population growth in developed countries and new techniques for cropping. However, even if the agribusiness sector were somewhat able to supply enough food; the concerns about environmental impacts of how we were producing the food gained attention and threatened 21st century society. Deforestation, loss of biodiversity, pollution of the air, water and soil, animal welfare, health implications of the food (mainly regarding the use of chemicals), amongst other issues are included in the environmental agenda of agribusinesses nowadays.

A more recent study by Hardin (1968) linked the dichotomy of individual and collective gains through a seminal paper entitled “The Tragedy of the Commons”. When individuals in a collective environment rationally try to maximise their gains, the collective gains may decline in the long term as a result of the over use of the resources at a rate with which the environment cannot regenerate itself. The tragedy of the commons is represented in a simulation shown in Figure 1.1. Figure 1.1 shows that in a closed system, A and B increase the overall consumption by trying to maximise their individual gains. In the long term, the continuous increase of their individual gains is impacting the carrying capacity of the commons. As a result, the commons cannot deliver the same productivity and the net increase of A and B’s activities will be reduced.

The ideas behind “The Tragedy of the Commons” has gained attention again lately because of alarming World’s population growth estimations. According to the United Nations, the World’s population will reach 9 billion people in 2050, mainly because of population growth in developing countries (United Nations, 2007).

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Figure 1.1 – Graphical representation of the “Tragedy of the Commons” (Kunsh et al, 2007)

With the industrialisation of countries after the 1800s and abundance of food, attention was drawn from agriculture systems to manufacturing industries and their harmful emissions. Manufacturing is indeed the largest source of environmental impacts due to the use of toxic substances, large consumption of water and energy, and disposal of dangerous wastes. While the environmental impacts were primarily from production and confined to local areas, environmental legislation became stricter and pollution control took place to avoid wasteful activities. Later, pollution prevention and process improvement was proven more economical and effective in response to meet legislation target (Klassen and MacLauglin, 1996; Klassen and Whybark, 1999a). Nevertheless, with the current globalisation of markets and production, the sustainability debate is led towards a more holistic approach which includes both production and consumption systems (Clark, 2007; Tukker et al, 2008). Hence, the modern studies of sustainability analyse the factories' location, production processes, logistics routes, product use and consumer behaviour, and ultimately, the final disposal of waste, be it an end-of-life product or residues of production.

Given the global scale and interdependence embedded into modern economies and business strategies, the discipline of Business has directed considerable interest to global issues such as anthropogenic CO_2 emissions and their relationship with global warming. Energy security, the strong dependence on fossil fuels and air pollution are raised in the Business research agenda (Kaya and Yokobori, 2002) as the pressure for sustainable development grows. Manufacturing, again, is one of the main points of concern due to its large consumption of fossil fuel and consequent CO_2 emissions.

Against this background, the World has undergone remarkable changes to its level of energy consumption, and consequently, the emissions of greenhouse gases. According to the International Energy Agency, as developing countries' economies grows towards a more industrialised phase, their emissions are the ones with higher positive growth. The World Resources Institute (2002) had already warned that the historical path of developing countries following the status of developed economies would increase energy use and emissions, particularly, CO_2 emissions. Figure 1.2 shows the change in CO_2 emissions by region for the period 2007-2008.

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Figure 1.2 - Change in CO_2 emission by region (2007-2008) (IEA, 2010)

Footnotes:
***China** includes Hong Kong
Annex II Pacific includes Australia, Japan, and New Zealand
Annex II North America includes Canada and the United States
Annex II Europe includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Monaco, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.
Annex I EIT (Economies in Transition) includes Belarus, Bulgaria, Croatia, Czech Republic, Slovak Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russia, Slovenia, and Ukraine.

The change in CO_2 emissions in developed regions shown in Figure 1.2 is a combination of both process improvement, and mainly, manufacturing offshoring and outsourcing to the developing countries. For instance, according to US researchers, in 2005, 14% of China's CO_2 emissions were accounted for by exports to the US (BBC, 2007). Despite the drastic increases in emissions from developing regions, developed countries lead the total emissions and emissions per capita tables worldwide. Figure 1.3 shows the top ten emitting countries and Figure 1.4 shows the emissions per capita in major World regions in 2008 (IEA, 2010).

Figure 1.3 - Top 10 emitting countries in 2008 (Gigatonne) (IEA, 2010)

Figure 1.4 – Tonnes of CO_2 Emissions per capita by major world regions in 2008 (IEA, 2010)

However, the complexity of the debate on CO_2 emissions cuts involves the socio-economic issues and measurement. The recent United Nations Climate Change Conference in 2009 in Copenhagen suggested how difficult it is to commit countries to reduce their CO_2 emissions. The conference results were criticised by several participants, environmental groups, and the media point out that there is very little consensus for concrete decisions. The pressure to reduce CO_2 emissions globally was raised in the 1990s in the global conference ECO 1992 in Rio de Janeiro and ratified by the Kyoto Protocol. The Kyoto Protocol (1998) suggested that industrialised countries should lead the emissions cuts, whilst at Copenhagen in 2009 – which was seen as Kyoto's successor, the pressure is now extended to developing countries and the agreement negotiations include China, India, Brazil, and South Africa, amongst others (Copenhagen Accord, 2009). Historically, the developed countries were responsible for the largest amounts of greenhouse gases emissions and if emissions per capita are considered, developed countries continue to be on the top as the largest polluters, as Figure 1.4 shows. However, as the emerging pressures for emissions cuts consider the absolute emissions, both developed and developing countries will need to make urgent and important decisions on how to reduce greenhouse gases (GHG) emissions as well as other initiatives towards a more low carbon world economy.

Hence, it is important to take a worldwide view of the sectors which are major contributors of GHG emissions. These sectors will tend to be the most affected when countries' low carbon policies are cascaded into business targets. Figure 1.5 shows that, globally, electricity and heat are the main sources of emissions being responsible for 41%, followed by transport (22%) and industry (20%). Indeed, there are country specifics that will need to be taken into account in order to have effective policies. For instance, Brazil where the climate is tropical in highly-dense populated areas, and the energy matrix is based on hydropower, transportation and industry tend to have a higher percentage of emissions, 41% and 30%, respectively. In the US, a strong dependence on automobiles makes transport the largest source of emissions, being responsible for approximately 33%, of which 60% is given by personal vehicles.

In contrast, the electricity and heat generation sector represents 48% of Chinese CO_2 emissions in 2008. The Chinese transport sector although growing rapidly, represented only 7% in 2008. Similar to China, India concentrates the emissions on electricity and heat (56%), while transport accounts only for 9%.

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Figure 1.5 - World CO_2 emission by industry sector in 2008 (IEA, 2010)

Analysing the Europe Union (see figures 1.6 and 1.7), a more developed and socially-economically homogeneous region, it is possible to note that industry and transport are responsible for more than 58.9% of energy consumption and 40.3% GHG emissions. Thus, it is expected that major changes to reduce GHG will need to come from these two sectors, alongside a change in the energy sector, since they are the largest sources of emissions.

Footnote:

*Other includes commercial and public services, agriculture and forest, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere.

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Figure 1.6 – EU Energy consumption by industry in 2006 (BBC, 2010 *apud Eurostat, 2010*)

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Figure 1.7 – EU GHG emission by industry in 2006 (BBC, 2010 *apud Eurostat, 2010*)

Considering the transportation sector, Figure 1.8 shows clearly that the focus of emissions cuts in transportation will need to be on road transportation. Figure 1.9 supplements the information showing that cars are actually responsible for 54% of the road emissions in UK while lorries account for 22%.

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Figure 1.8 - CO_2 Emissions from Transport in 2007 and 2008 (in Megatonne) (IEA, 2010)

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Figure 1.9 – UK Transport sector carbon emissions by mode in 2005 (excludes international aviation and shipping) (CfIT, 2010)

Given that cars are responsible for 54% of the road transportation emission, it is natural that the major pressures target the passenger private vehicles. However, it is important to highlight the relevance of lorries and vans as sources of carbon emissions, with respectively 22% and 13%. In fact, commercial vehicles and passenger cars have different characteristics and patterns of use and manufacturers could use different strategies when greening these products.

This section (Introduction to Sustainability) has briefly presented the evolution of sustainability challenges. At the global level, it was eventually agreed in the climate change forums (ie., the agreements signed in Copenhagen and Cancun) that CO_2 should be used as a key measure in order to promote global sustainability. The evidence provided in this section highlights that transportation and particularly the car manufacturers will be strongly affected as low carbon policies are implemented worldwide. Companies will be required to accommodate the CO_2 emission reduction in their environmental agenda – how to do this in a cost-effective way will be a challenge for all industries, especially automotive.

The next section presents the research problem into the wider context of sustainability in which companies operate and take environmental decisions.

1.2 Contextualising the research problem

Amidst the global warming discussions, nations will be developing their own strategies, objectives, and goals to reduce carbon emissions. These decisions will have an impact on corporations and consumers as the policy decisions are cascaded into market incentives and emissions limits to each industrial sector and product utilisation. As manufacturing has historically been seen as one of the main sources of pollution, we expect that stricter laws will have particular focus on manufacturing industries.

In addition to the increasing demands for reduction in carbon emissions, manufacturing has also to deal with decisions related to elimination of substances of concern (for both products and processes), reduction of waste streams due to the scarcity of landfills, and water conservation issues amongst others. In fact, the consideration of the environment, as part of the business, is now inevitable and a clear point of concern in management, especially for global corporations.

Being a strategic issue, sustainability must be analysed taking into account the nature of sectors, organisations, processes and products within a society. A systemic approach to understand the impact of an organisation on the economy, society, and ecological environment would become a challenging principle (Capra, 2002).

Fundamentally, the economy belongs to a society, which itself belongs to the ecological environment. In addition, rather than it being a static relationship, there is an inter-dependence of the economic sphere with the spheres of the social and ecological system (see Figure 1.10). It is the balance between these systems that allows sustainable creation, growth, and welfare. This inter-dependence is existent between the environment, society and its economy, which makes each sphere create positive and negative impacts on the others. For example, the environment may harm the economy and society through an earthquake or a volcanic eruption, while for example society may harm the economy due to the lack of trust and weak public institutions. On the other hand, economic activities and anthropogenic actions may damage the environment with pollution and depletion of natural resources. It is also possible for the environment to create a positive impact on the socio-economic system and vice-versa. Consider the natural resources available to nourish people and grow economies. From the opposite direction, economic activities may help societies (e.g. educational institutions, hospitals etc) and conserve or enhance the environment (e.g. water treatment stations, soil and vegetation management etc). In summary, sustainability is not only the need to respect the bottom line of the three “Ps”– Planet, People and Profit

- (Kleindorfer et al, 2005), but also in the need to harmonise people's desires for a joyful life.

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Figure 1.10 – A systems approach to sustainability management (Nunes and Bennett, 2010)

These new concerns in greening businesses have increased complexity and importance of environmental decision making in organisations. Thereby, they are related to the main research problems this PhD thesis will address.

The focus and scope of the thesis is mostly on manufacturing companies, with particular interest in the automotive industry. Traditionally, the automotive sector is regarded as one of the largest manufacturing enterprises with massive contribution to economies, employment, and welfare. However, these benefits are now under discussion as the industry's environmental burden is considered high and visible. Auto companies will need to take important strategic decisions to continue in business, including the accommodation of sustainability issues into their business agenda. The size and complexity of the sector makes environmental decision making difficult as it is not easy to determine where to invest when there are so many different demands for distinct areas of the operations function. For instance, companies will face the need to invest in facilities, product design, supply chain, production processes, reverse logistics, etc. Their future will be dependent upon the quality of their decision making processes, and ultimately, on the robustness and implementation of the decisions themselves.

1.3 Research Questions

The research questions in this PhD thesis were developed first from the identification of a gap in the literature oo green operations and supply chain studies. The gap is pointed to by several authors but particularly more explicitly in the papers by Zhu et al (2005), Zhu et al (2007), and reinforced later by Sarkis (2010). Zhu et al (2005) were not able to confirm the connection between drivers, environmental practices implementations, and the consequent performance improvements in green supply chains as they theoretically expected. Investigating the automotive industry, Zhu et al (2007) were also unable to validate their hypotheses through a questionnaire survey, however depth and enhancement on these causal relationships were found when using case research strategy with qualitative methods. The importance and up-to-datedness of these factors were reinforced recently by Sarkis (2010), who edited the special issue 'Benchmarking the Greening of Business' (in *Benchmarking: An International Journal*) and concluded that although the drivers for greening are very much the same as in the past, they could be now more pronounced and dependent on contextual issues such as economic climate and geopolitical forces.

There are four research questions that were aimed to be answered in this study. They are presented below with a brief explanation about the relevance of each of them.

RQ1: In what way does the context play a role in the environmental decisions of companies?

Naturally, companies are benchmarking themselves against competitors. Moreover, government, customers, amongst other important stakeholders, create pressure amongst companies to adopt “best practices”. Nevertheless, companies operate in different countries; have different organisational and national cultures, and other factors that may impede the diffusion of practices worldwide. Due to this fact, this question was considered in an environmental report analysis for three large automotive corporations. Environmental practices composed a roadmap for the sector and were benchmarked in order to investigate the role of the context in adopting environmental practices.

In addition, personal interviews allowed investigating how companies deal with transfer of knowledge and environmental technologies in different countries

RQ2: What are the drivers for manufacturing companies to take environmental decisions?

Indeed, it is not an easy task to take environmental decisions in the automotive industry, the largest manufacturing industry in the world. In theory, environmental strategies are dependent on environmental impact assessment studies, customers' desires, wider environmental policies, competitors' behaviours and cost amongst other factors. However, are there different drivers for different activities within the operations function? How does one driver impact on the others?

To answer this question, this PhD thesis investigates the reasons why companies take environmental decisions. Personal interviews were conducted with environmental managers and their teams, as well as with other decision-making teams in the operations function such as product development and supply chain. Managing directors and their immediate teams were also interviewed when possible and a focus group was conducted in two of the nine cases.

RQ3: Where do (environmental) solutions come from?

It is important to track the origin of ideas for environmental decisions. This will improve the understanding of the role of different stakeholders in the decision making process and may provide powerful insights on where to act in order to establish a better decision making process. For instance, the role of Environmental Agencies has been changing over recent years from developing and enforcing command and control policies to developing pollution prevention programmes, and stimuli to environmental innovation. This question aims at discovering the origin of the environmental solutions. Environmental advocacy groups such as Greenpeace have also become solution-providers rather than merely exposing the environmental impacts of organisations. These external pressures may foster innovations outside-in if the solutions are valuable for companies. Likewise, the role of consultants, internal experts, suppliers, universities, and other possible stakeholders need to be better understood.

This question was dealt with as part of the semi-structured questionnaire used in the interviews and focus group activities run in the data collection phase of this research investigation.

RQ4: How does a structured approach contribute to effectively improve environmental decisions?

Following the preliminary results from research questions one, two and three of this PhD research, it was found that companies do not have a structured approach for taking environmental decisions. Environmental decisions tend to be conducted in the business-as-usual way without giving the strategic attention they may deserve. In order to increase the practical contribution of this thesis, the author developed a process based on the systems thinking principles to help companies with their environmental decision making processes. This is named the *GRASS (Greener Approach to Systems Strategy)* model.

The testing of the model was carried out in a higher-education institution, which was taking decisions on how to green their research and teaching. Through a focus group, the model was applied and evaluated by the participants.

1.4 Objective of the Thesis

Considering the context of the research problems and the questions raised for investigation, the main objective of this thesis is to understand the structure of environmental decision making, including its strategic alignment, the main drivers, and origin of ideas. As a second objective, this thesis proposes the *GRASS* model as a systems approach to taking strategic environmental decisions, which aims at improving the environmental decision making process within organisations.

1.5 Relevance and Contribution of this study

This thesis has both theoretical and practical relevance, which can be represented by its contributions. There are four major contributions of this study, namely:

First, the categorisation of green operations practices used in Chapter 4 for analysing the environmental reports. The classification will contribute to the expansion of knowledge in green operations and will constitute a clearer way to benchmark environmental practices. Second, and still within the findings of environmental reports, the roadmap of environmental practices used by GM, Toyota and Volkswagen will benefit practitioners in the sector when developing their strategies, and environmental programmes within their environmental management systems.

Third, from the insights gained through the case studies, it was possible to advance an understanding of why and how companies implement environmental practices as well as the characteristics of their decision making process. For example, it was found that companies are keen on "going green" with manufacturing process because it is clear how they are going to profit in the future due to the reduction in waste and consumption of resources. However, there is less support for possible environmental initiatives relating to the design, facilities, supply chains, and disposal as it is uncertain how companies will profit from these. Hence, the environmental initiatives for those areas tend to take place when legislation pressures the firm rather than due to proactive behaviour. Case study research has also provided a deeper knowledge on how environmental decision making processes are structured and the fact that acting beyond the manufacturing transformation activities such as supply chain, product development, reverse logistics, and facilities management will add uncertainty and complexity to corporate decisions. Notwithstanding the complexity and risks involved, leading companies understand the strategic importance of greening product development, processes and manufacturing and non-manufacturing activities as their image and competitive leadership depends upon achieving excellence in these areas.

Last but not least, this thesis offers a systems model (*GRASS)* which aims at improving environmental decision making in organisations. Since more and more companies will have to make important decisions in the near future, the model can be understood as both a theoretical and a practical contribution. The application and evaluation of the model in a real decision making experiment has provided insights that will also impact the theory and practice of environmental strategies.

1.6 Structure of the thesis

This thesis is organised into 10 chapters. Chapter 1 presents the thesis introduction where the research problem is contextualised; objectives, contributions, and structure are presented. Chapter 2 presents the literature review and is divided into five sections: (1) introduction to business sustainability, (2) the theory of green operations, (3) green operations practices, (4) environmental decision making and (5) the unsustainable context of the automotive industry, which is the sector in which much of the company case study is conducted.

Chapter 3 is the methodology chapter. This chapter shows the research phases and explains why case research is the main research strategy adopted in this thesis. Chapter 3 also justifies the use of research methods and instruments and how they are linked to each research question. The presentation of the findings of this thesis starts in Chapter 4, which sheds light on the environmental report of the largest automotive enterprises in USA, Europe, and Japan. General Motors, Volkswagen, and Toyota's environmental (or sustainability) reports are investigated and discussed in Chapter 4.

Chapters 5 and 6 present the findings of case study research on the automotive and non-automotive sectors, respectively. These chapters present the drivers, origin of ideas, and environmental decision making processes by the environmental teams within the companies. The scope was the operations function, which allowed the participation of teams from different operations activities, namely: product development, supply chain, and manufacturing. The discussion of these findings is presented in Chapter 7.

In Chapter 8, the Green Operations Framework and the rationale of the *GRASS* model are described. Later in this chapter; the *GRASS* model application and the lessons learnt from it are presented.

Chapter 9 presents the conclusions of this PhD study. It summarises the conclusions from analysing environmental reports, interviewing environmental decision making teams or individuals responsible for environmental decisions, and insights from the model application. Chapter 9 is completed with a discussion on the limitations of the study, future research, a reinforcement of its contribution for theory and practice.

1.7 Chapter Summary

This chapter presented the introduction of the thesis. It was intended to highlight the importance of sustainability in the business context, and provide a preamble for the research questions investigated in this PhD project, with their respective links to the existing literature gaps. The objective of the thesis is also presented alongside the contribution of the PhD results and conclusions. Finally, the structure of the thesis was presented showing that this study contains nine chapters.

While the Introduction Chapter of this thesis sets the relevance and urgency of green operations in the automotive industry and the need of better environmental decisions, the next chapter will present a literature review which will expand the understanding on why and how companies make environmental decisions. It will also become clearer why environmental strategies need to go beyond CO_2 emissions in order to be truly sustainable.

Chapter 2 - Literature Review

This chapter presents the relevant literature to this thesis. The introduction contextualises the global nature of today's supply chains, which reflects the importance of operations management for business sustainability. The greening of the operations function is given by both integration of environmental concerns in the strategic decisions and implementation of environmental practices. These issues are presented in this chapter in the sections 'Theory of Green Operations' and 'Green Operations Practices'. The final sections of this chapter contain the literature on environmental decision making (including systems thinking), and finally, an overview of the automotive sector, since it was the main industrial sector studied in this research.

2.1 Introduction to Business Sustainability

Economic globalisation has brought a number of benefits for many countries, namely reductions in operational cost, increased employment opportunities, and the supply of essential goods and services to a larger part of the global population. On the other hand, the World has faced sustainability problems relating to the new (and higher) scale of both production and consumption, which have become a threat to the renewal of our natural resources and the roots of local and global pollution of water, land and air. The discussion of sustainability at a global level is not new, having been part of some early studies on production systems. It is even associated with the collapse of ancient civilisations (Malthus, 1978; King, 1995; Hardin, 1968; Kunsch et al, 2007). As recent fears emerged about high pollution levels, depletion of natural species and flora, with unprecedented fast and high rates of consumption, "sustainable development" was chosen as the path for continuous progress of the welfare and wellbeing of our society.

Sustainable development is considered to be development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WECD, 1989 p.54). More related to the globalisation phenomena, two schools of thought have typified the discussion about the impact of globalisation on the environment. One school argues that globalisation hurting the environment is not well-founded, having the "Environmental Kuznets Curve" (EKC) as its basis; while the other school argues that EKC is incomplete because it does not consider nature's carrying capacity, accumulative pollution and irreversible damage on the environment (Tisdell, 2001). Also, it argues that EKC is incorrect for a number of pollutants including CO_2.

Figure 2.1 shows EKC added with the CO_2 emissions behaviour when income per capita grows. Researchers have found that at a US$ 8,000 income per capita, societies tend to have satisfied most of their basic needs and the concerns with the environment emerge making it an inflexion point where the emissions of harmful pollutants will stop increasing and start decreasing (Tisdell, 2001; Hill, 2007).

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Figure 2.1 The Environmental Kuznets Curve (EKC) of added CO_2 emissions behaviour (Hill, 2007)

The discussion about economic growth, globalisation and sustainability is still ongoing and the EKC continues to be controversial. Surprisingly, very little has been discussed in the operations management literature to add a perspective and contribution to this debate. Operations management is the discipline that can embrace the strategic and operational issues of locating new production sites, technology choice, product design, quality, logistics routings, and supply chain design including inventory levels, distribution centres, etc. Thus, the globalisation of production is an important factor to be taken into account when greening business operations.

In fact, the impact of globalisation on supply chain management has been discussed extensively in a number of publications showing the benefits (e.g. access to cheaper resources, location advantages, efficiency gains, access to new markets, etc) and negative implications such as increased complexity and risk in global supply chains due to the long distances and high uncertainty (Dornier et al, 1998; Ballou, 2007; Friedman, 2007; Lee, 2004; Liker and Choi, 2004; Power, 2005). However, most of global operations initiatives discussed in the literature refer to market and/or resource seeking, the environmental and social issues were frequently neglected. Therefore, successful globalisation of supply chains primarily was defined only from a financial perspective, and considered as achieved when meeting the requirements of reducing costs, gaining markets or establishing a global presence (Levitt, 1983; Arntzen et al, 1995). An operations-based approach has brought to the debate the issues about capacity, technology, logistics, risk, and complexity when globalising operations (Dornier et al, 1998; Hayes et al, 2004). Indeed, as a consequence of globalisation, distances have increased, as have the risk and interdependence across the countries and companies, not only in the same but also in different global production networks. The difficulties of coping with unpredictable demand variations, more complex supply and production forecasting, exchange rate fluctuations and macroeconomic uncertainties have created great challenges for inventory control, transportation, distribution and procurement. When efficiency gains (from the lean production philosophy of the 1980s) were not solely sufficient to compete in the global markets, supply chains had to develop the ability to be agile, adapted and aligned with partners in the 1990s (Lee, 2004; Katayama and Bennett, 1996; Katayama and Bennett, 1999).

In the 2000s, environmental issues have attracted attention in the supply chain debate by environmental management establishing its status as a key area to improve operations (Corbett and Klassen, 2006; Beamon, 2005; Beamon, 2008). Hence, being an important aspect of operations, environmental philosophy had to be passed forward to suppliers in order to maximise performance and reduce risks (Kleindorfer et al, 2005; Vachon and Klassen, 2008; Seuring and Martin, 2008; Geffen and Rothenber, 2000). However, measuring environmental performance continued to be a difficult task and the understanding of the drivers, pressures, initiatives and their impact on performance becomes a vital step in taking the right environmental decisions in the supply chain (Zhu et al, 2007; Hervani et al, 2005; Zhu et al, 2005). In fact, the literature has explored in detail research problems regarding pollution prevention, energy and water consumption, waste management, reverse logistics, environmental performance measurement and drivers for “going green” among various topics under the general umbrella of green supply chains.

Hall (2000) listed the sources of pressure on companies to have sustainable behaviour, namely (among others) regulation, consumers, customers, stakeholders, investors, environmental lobby groups, employees and unions. Once these pressures affect an organisation, they may be passed on to its suppliers; hence the organisation will share both risk and responsibility. Behind the pressures for greening the supply chain and the associated initial investments there is a huge opportunity to reduce costs for product and process simplification and performance improvement (Corbett and Klassen, 2006; Kleindorfer et al, 2005; Vachon and Klassen 2008; Angell and Klassen, 1999; Sarkis, 2003; Gupta and Sharma, 1996).

For example, Gupta and Sharma (1996) argue that environmental operations management may impact positively on operations performance. The authors discuss their proposition based upon operations performance criteria: dependability, efficiency, flexibility, and quality; as well as on operations decisions: quality management, process design and selection, capacity planning and scheduling, inventory management, and work-force management. Other authors have noticed the increasing awareness about environmental issues in the research agenda of manufacturing strategy, which needs to be aligned now in the context of green manufacturing (Dangayach and Deshmukh, 2001; Azzone and Noci, 1998).

Nonetheless, these “hot-spot” win-win solutions have not always been possible (Orsato, 2006); thus companies were challenged to implement environmental practices in the most cost-effective manner. Once the boundaries of the actions undertaken by firms were beyond internal operations, the extended view of environmental management towards the supply chain became justifiable; particularly to avoid the transfer of environmental impacts within outsourcing practices given the different legislation in different countries (Brown, 2008). This raised difficulties, but also opportunities in having cost reduction in the up-stream supply chain.

In conjunction with the outsourcing trend, Child and Tsai (2004) explain that companies will indeed face different institutional constraints in different countries that could affect the firms' strategy and the results of their behaviour (environmental proactive or reactive attitudes). Besides the regulatory concerns, van Hoek (2002) highlights the need of environmental initiatives to be in accordance with market requirements (upstream supply chain). This author also brings in Reinhardt's approach (Reinhardt, 2000) to discuss the possible advantages from economies of scope. For van Hoek (2002), an environmentally friendly supply chain would need to consider all activities: raw material acquisition, inbound logistics, transformation processes, outbound logistics, marketing and after-sales services. Nevertheless, due to the extension and complexity in global supply chains, a company would need to think about greening its supply chain in a strategic way, in order to increase the chances of effective implementation.

According to Seuring and Martin (2008) the literature shows that companies green their supply chain with two objectives, i.e. (i) supplier management for risks and performance, where emphasis is placed on avoiding risk from suppliers with poor performance on set environmental and social standards; this situation might require additional criteria for supplier evaluation, and (ii) supply chain management for sustainable products as a more proactive strategy.

While the impact of environmental regulation has been explored extensively in the literature (Jaffe et al, 1995; Porter and Linde, 1995a; Smith and Crotty, 2008), a more holistic view of green supply chains is needed as well as a new way of thinking about environmental improvements (Beamon, 2005; Beamon, 2008; Orsato, 2006; Porter and Linde, 1995b; Azapagic, 2003; Hart, 1995; Hart, 1997; Haskins, 2006).

Nevertheless, in the global arena, where competition occurs, the level of complexity for systems approaches (such as life-cycle analysis) is strengthened and there is the risk of ending in a paralysing situation (Orsato and Wells, 2007). All this suggests that the debate about sustainability in global supply chains should occur at the strategic level first. For instance, Porter and Kramer (2006) pointed out the importance of having sustainability issues embedded in the business strategy agenda.

The basic start to understanding how to build more environmentally-friendly companies is by reviewing the green operations literature, which follows in the next section.

2.2 The Theory of Green Operations

Among all functions of a company (i.e. finance, marketing and operations), the operations function is the greatest source of environmental impact and therefore, the most important to find opportunities to reduce environmental burdens from the organisation's activities. The operations function of a company encounters environmental protection issues directly because it is the main source of harmful emissions. Thus, environmental management programmes and policies should be carefully developed to strengthen its operations strategy (Gupta, 1995).

The theory of Green Operations is presented in mainly two approches: (1) which advocates the considerations of environmental issues in the decision making process, and (2) which considers green operations based upon the use of environmental practices. Indeed, the industrial ecology approach tries to merge both decisions and use of practices in a philosophical dimension, in which the company's production processes are part of a greater production and consumption network that resembles an ecosystem.

Within the first approach, Gupta and Sharma (1996) define Environmental Operations Management (EOM) as the integration of Environmental Management principles with the decision-making process for converting resources into usable products. They believe that EOM is a strategic level of operations management since it primarily concerns product and process design. In fact, defining the strategic operations objectives (cost, quality, speed, flexibility and reliability) is strongly connected to environmental issues.

Gupta and Sharma (1996) illustrate this EOM concept using (i) operations management performance criteria: dependability, efficiency, flexibility, and quality; and (ii) operations decisions: quality management, process design and selection, capacity planning and scheduling, inventory management, and work-force management.

Taking the same perspective, the Canadian Department of Foreign Affairs and International Trade – DFAIT - conceptualise the aim of Green Operations as the integration of environmental considerations into day-to-day operations (DAIFT, 2006). This ensures that operations are conducted in a manner consistent with good environmental stewardship principles and practices while taking into account competing demands on financial and human resources.

With the second approach, the use of environmental practices, Sarkis (2001) has designed the concept of greener manufacturing and operations through the use of environmental tools such as: design for environment, green supply chains, total quality environmental management and reverse logistics. Similarly, Kleindorfer et al (2005) has identified the evolution towards sustainable Operations Management is clear in three areas that integrate the three Ps (People, Profit and the Planet) of sustainable operations management: (1) Green product and process development, (2) Lean and green OM and (3) Remanufacturing and closed-loop supply chains.

Green Operations is in fact a concept that interests practitioners and researchers. A survey of the literature points to four major environmental management research streams that relate the natural environment to operations management in an increasingly focused manner: sustainable development and industrial ecology; strategy and corporate social performance; environmental technology and innovation; and Total Quality Environmental Management (TQEM) (Angell and Klassen 1999).

Angell and Klassen (1999) also highlight the dilemmas and challenges for environmental management in the literature, such as: Should environmental management be considered a separate research stream with its own strategic framework, or should environmental issues be integrated into existing operations management research frameworks and areas? They argue that while the complexity of environmental issues might favour the former approach, the greatest contributions can be achieved by pursuing opportunities within a more integrative framework.

In fact, dealing with possible sustainable solutions is a complex task. One reason is by reducing environmental impacts at specific points in a product life. For example, reducing energy consumption in the usage phase, may be of little or negative value if other changes also occur such as increasing energy consumption in manufacturing and recycling (Mildenberger and Khare 2000).

Life-Cycle Analysis (LCA) is a technique that appears as a holistic approach to avoid the transfer of environmental impact from one phase of the life-cycle (of a product or process) to another phase. Nevertheless, while in principle, it is a straightforward concept, the life-cycle approach can be swamped by complexity and the minutia of data requirements (Orsato and Wells, 2007). Even so, Orsato and Wells (2007) consider that there is a coherence behind seeking to identify all aspects of the impact of a product, not least to ensure that ‘improvements’ made in one area do not conflict with ones in other areas. Moreover, given that, as noted above, the resolution of multiple requirements to attain a more sustainable industry may well result in the problem becoming so large and difficult that it becomes impossible, it is practical at least to focus on more manageable problems (Orsato and Wells, 2007). For these reasons, Orsato and Wells (2007) affirm that there is a tendency to step back from systemic solutions, and to examine particular aspects of the industry in more detail.

Indeed, the discussion about how to integrate environmental issues in the company’s activities needs a continuous reflection. Angell and Klassen (1999) highlight that when the literature on environmental management in operations is broadly examined and synthesized, two dominant perspectives emerge: the External Constraint and the Component perspectives. The first, which historically dominated much of the operations management literature, considers environmental performance requirements to be an externally imposed constraint on the operating system. In contrast, the component perspective recognizes environmental issues as legitimate operating factors, with implications for operations strategy. For them, most importantly, the second perspective explicitly recognizes the potential for operations to plan for influencing and leveraging environmental issues for competitive advantage both internally and externally.

An interesting approach is to consider Environmental Management as a strategic tool. In this way, at a corporate level, the environmental SWOT analysis can help to identify external threats (e.g. competitors gain market shares with green products) and opportunities (e.g. offering an "environmental-friendly" product), and relate them to internal strengths (e.g. research and development capabilities for "clean" processes and "green" products) and weaknesses (e.g. hazardous wastes) of a company (Gupta and Sharma, 1996).

Therefore, after identifying environmental threats and opportunities or setting sustainability challenges, a company should consider which activities of its operations function are affected or could contribute to the development of a sustainable competitive advantage. It is important to note that there already exist practices that might facilitate the company's path towards a sustainable future.

Although much has evolved in terms of knowledge as well as in practice; pursuing environmental leadership continues to be a daunting and complex task. Most environmental decisions are very fuzzy, and there are many other issues that need to be addressed in accordance with non-environmental factors such as (to name just a few) investment or cost feasibility, customer satisfaction and quality requirements. Furthermore, it is fundamental to consider that environmental initiatives compete against other prospective projects in an organisation (marketing campaigns, production capacity expansion, quality improvement, etc). On the other hand, public pressure, legislation, possible cost reduction and improved image may be a sufficient motivation to improve environmental performance.

Indeed, the progress can be seen by the historical path of environmental management. Beamon (1999) shows how environmental management evolved from pollution control and risk management in the 1970s to pollution prevention in the 1980s with a focus on the implementation of systematic product and process management, ISO 14000 series launch, and the emergence of life cycle and industrial ecology approaches. The further evolution of environmental management leads to its recognition as a key area for those who want to be competitive in modern times (Corbett and Klassen, 2006). Nonetheless, as a key area of improvement, environmental management will need to be taken under a systemic approach (rather than systematic), i.e., analysing how the decisions will impact not only on the environmental aspects but also the overall business and operations strategy. In fact, a number of authors have already identified the need for a systems view of environmental issues (Frosch and Gallopoulos, 1989; Sarkis, 1995; Hart, 1995; Angell and Klassen, 1999; Klassen, 2001).

While the question of why a company should implement environmental management practices may have already been answered, there are still many other questions that need further investigation. For instance, even if there is an "environmental budget", how are companies making environmental decisions? To define where a company is supposed to invest is a very challenging and strategic decision that involves various possibilities (e.g. facilities, manufacturing, logistics, marketing, process and product design, etc). Another difficult aspect of environmental initiatives is how to implement them in a way to also meet corporate goals of profitability, as well as other business requirements. This may happen because of the elementary reasoning behind environmental protection. While most of the business practices return private profits; environmental protection is strongly recognised as a public good (Orsato, 2006). Indeed, it is not always the case that environmental management initiatives will return a profit for an individual initiative or provide a match with all corporate objectives. There will be conflicts, mainly when the initiatives are taken under an opportunity cost analysis. However, the more businesses consider the importance of managing intangibles, the more environmental issues will become better commended and prove valuable, even starting with an economic or financial analysis.

For all these reasons, environmental and sustainability management are, in fact, strategic subjects. There is a significant need to investigate the place of environmental strategies, the rationale behind them, their implementation, and finally, the measures of success used, as well as the coherence between implementation and the goals previously established.

The lack of a precise classification of green operations practices is clear in the literature. Another problem is a perspective of environmental performance that is only based on process performance. For instance, there is no integration so far of environmental performance of product and process to analyse operations function.

The next section discusses the Green Operations Practices (GOP).

2.3 Green Operations Practices

Several studies identify the set of practices to achieve environmentally-friendly production of goods and services. However, the conceptualisation of these practices is not well described. In this chapter, a concise set of these green operations practices is presented with the intention to match all major activities of operations function. First, in order to cover all activities, this study identified and included the Green Buildings practice, which is rarely discussed in operations management. Figure 2.2 (the Green

Operations Practices) includes Green Buildings considering that the phases of construction or expansion of production plants are important for the business sustainability. Second, it is important to characterise these practices and their benefits as well. The role of innovation in greening operations is also discussed here and its importance as part of the environmental strategy is represented in Figure 2.2 too.

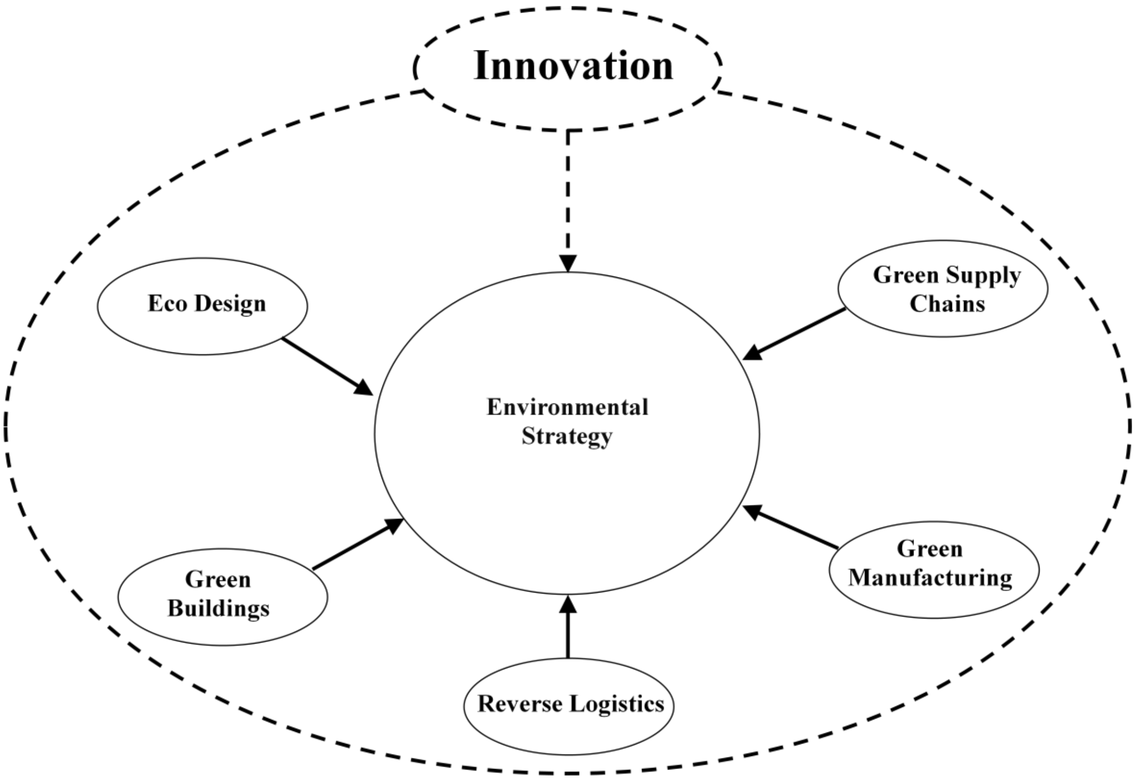

Figure 2.2 – Green Operations Practices and innovation as part of the Environmental Strategy (*Developed by the author based on the literature)*

The theory of green operations does not offer a standardised classification on environmental practices. Different terminologies are usually found on the field causing confusion and difficulties to build a robust classification. For instance, a number of studies include Eco-Design as part of Green Supply Chains. In addition, Green Supply Chains are also known as closed-loop supply chains, which include Reverse Logistics. Considering the differences from practice, drivers for implementation, and the nature of their activities, these green operations practices were considered distinct from each other, hence, the choice of having the forward logistics as part of Green Supply Chains but Reverse Logistics and Eco-Design as a separate practices. This does not mean they do not interact in reality though as the scope of these may overlap in some companies.

2.3.1 Green Buildings

Environmental issues should be taken into account from the very beginning of the operations cycle, i.e., from the planning and construction of an industrial plant.

Paumgartten (2003) presents figures about the USA, where non-residential buildings are responsible for 30-40% of all the nation’s energy consumption, 30-40% of atmospheric emissions, 60% of all electricity use, 25% of all water use, 35-40% of the municipal solid waste stream, and 25-30% of all use of wood and materials. Analysing the whole life of a building, construction costs account for only 11% of its total cost, whereas operation and alteration costs amount to 75%. The remaining cost refers to capital cost involved in the financing of buildings.

The core idea of Green Buildings is to reduce operational costs through better environmental performance. For example, the criteria used by the “LEED” (Leadership in Energy and Environmental Design) methodology of the US Green Building Council to assess environmental performance of a building consist of the sustainability of the site (e.g., using green or brown fields, proximity of markets or suppliers, etc.), water efficiency (e.g., use of rainwater), energy use (e.g., intelligent control systems.), resources and materials (e.g., use of certified wood, etc), indoor environmental quality (e.g., low emitting materials of volatile organic compounds) and finally, innovation and design process (e.g., use of innovative techniques) (GBA, 2003).

Silva (2003) lists the main existing systems for environmental evaluation of buildings, namely: LEED (USA), BREEAM (UK), HK-BEAM (Hong Kong), EPIQR (Germany), EcoEffect (Sweden), BEAT 2002 (Denmark), EcoProfile (Norway), PromisE (Finland), BREEAM Canada (Canada) among other methods. These methodologies have several similarities. For instance, BREEAM-UK has served as a platform to develop assessment methodology in Canada and other countries.

Ries et al. (2006) affirm that there are five major areas of improvement from green buildings practices: (1) gains in worker productivity, (2) reductions in health and safety costs, (3) improvements in indoor environmental quality, (4) reduction in maintenance costs and, (5) energy and water savings.

These practices are also important to non-manufacturing activities (sales centres, offices, etc.) where energy and water usage may be the main environmental concerns. Another concern relating to companies' facilities is the end-of-life of their buildings and the residual financial value.

2.3.2 Eco-design

This practice refers to the environmental concerns in product or process design and, as such, it influences the entire life-cycle of a product. For example, Mildenberger and Khare (2000, p. 205) say about the long decision lead time in the automotive industry: "According to the German car-maker BMW, it takes about 3-4 years to design a car, 7-8 years to manufacture it, and it would be in use for about 10-12 years; thus, in all, a decision taken today will have its effect for about a quarter of a century if it is not victim of irresponsible disposal of waste.” Moreover, product design is often complicated by uncertainty inherent in the evolution of environmental trends and regulations (Kleindorfer et al., 2005).

Among characteristics such as functionality, product safety, comfort, efficiency and aesthetics, R&D teams are also required to consider the impact of the product/process on the natural environment. Karlsson and Luttropp (2006) argue that Eco-design also ought to include concepts such as sustainable consumption, reduction of the volume of “desire” and aims to enable human satisfaction in concert with a positive role in sustainable product development. As an example, power and speed have been differentiators for some car automakers, although their customers are not usually allowed to drive their vehicles at high speeds due to the traffic law.

For Sarkis (1998) Eco-design has a number of functional sub-components: design for reusability, recyclability and remanufacturing; design for disassembly; and design for disposal. To achieve successful implementation of Eco-design practices it is essential to have a combination of customer needs and desires with respect to the environment, aimed at bringing satisfaction and functionality. Last, but not least, communication throughout the organisations’ functions (marketing, engineering, etc.), and avoiding concentration and isolation of R&D teams is noted by Boks (2006) and Sandstrom (2001). The interaction, communication and commitment of people outside R&D can avoid a non-feasible idea from going to implementation causing further and higher costs.

2.3.3 Green supply chains

As supply chain management gains importance in the strategic decisions, it has also gained concerns related to the management of social and environmental issues.

The concept of Green Supply Chains (GSC) brings environmental and sustainability issues within the buyer-supplier relationship. According to Gilbert (2001), greening the supply chain is the process of incorporating environmental criteria or concerns into organizational purchasing decisions and long-term relationships with suppliers. Geffen and Rothenberg (2000) discuss how suppliers can be important in environmental innovation. Indeed, green supply chain practices include a range of initiatives across activities such as transportation, material handling, manufacturing, storage, distribution, packaging, purchasing and transfer of technologies to suppliers.

Between 1996 and 2002, the cost of materials bought by the 100 biggest US manufacturers increased by almost 12%, according to Purchasing Magazine's estimates (Liker and Choi, 2004). Moreover, in 2001, the Malcolm Baldrige National Quality Award Committee made "key supplier and customer partnering and communication mechanisms" a separate category on which it would judge the best companies in the United States. These facts show how important it is to promote a solid and sincere relationship with suppliers, to build competitive advantages. Indeed, there are three approaches involved in the development of a GSC: environmental, strategic and logistical (Nunes et al, 2004). Considering the environmental sphere, a company could consider the use of cleaner fuels for transportation, green purchasing and also transfer of environmental technologies to suppliers. As GSC also involves long-term relationships with suppliers, there is a strategic approach involving the selection of suppliers, partners, and the knowledge or technology to be transferred. These are strategic issues that might affect the factors of adaptability, agility and alignment of objectives in the supply chain. The third approach relates to logistics. Thus, GSC would also need to be considered taking into account costs, feasibility to move, store and distribute material, personal training, etc.

Gilbert (2001) supports the idea of two categories of initiative to stimulate greener supply chains. The first involves better coordination with suppliers on environmental efforts to enable development of greener or more environmentally friendly products. The second is demanding improved environmental performance at suppliers' operating facilities, such as the requirement to obtain the environmental management systems ISO 14000 certification or achieve a set standard of performance. In the US, the Environmental Protection Agency (EPA) shows that proactive management of supplier environmental performance can lead to product and process simplification, more efficient resource utilization, quality improvement, liability avoidance, and enhanced leadership image (EPA, 2000).

In short, green supply chains will predominantly include environmental concerns into selecting and managing suppliers, transferring technologies, and reducing environmental impacts of logistics and warehousing activities.

2.3.4 Green manufacturing

For the countries of the OECD (Organisation for Economic Cooperation and Development) manufacturing accounts for 40% of sulphur dioxide emissions (the precursor of acid rain), 60% of water pollution, 75% of non-hazardous waste and 90% of hazardous waste (OECD, 1995). As a result, research spanning the engineering, natural sciences, public policy, economics and business literature has proposed various strategies and actions to improve the environmental performance of manufacturing (Jones and Klassen, 2001).

The concept of green manufacturing is based on the philosophy of industrial ecology. The basic aims of green manufacturing are to increase efficiency continuously and therefore, "Reducing" the use of inputs through a reduction of waste. "Re-use, "Re-manufacturing" and "Recycling" complete the fours "Rs" of industrial ecology. It is important to highlight the level of energy required to reduce, re-use, re-manufacture and recycle. "Reducing" is the most important practice from the point of view of energy conservation.

"Reducing" is the most important practice from the point of view of energy conservation. In his essay published in Best American Science Writing 2003, the Physicist Marcelo Gleiser summarises:

> We must learn from the way Nature operates. There is a single principle behind all existing order in Nature (…) Humans cannot escape this alliance with the rest of the cosmos. Our tensions are part of this universal trend, our creations and destructions are part of the same rhythms that permeate the Universe. However, we have distanced ourselves from Nature, and have become wasteful. Nature is never wasteful, it never uses more energy than it has to, it never chooses a more costly path to achieve the same end result. This is true of atoms, of bacteria, of elephants, and of galaxies. Our wastefulness is reflected in the way we treat our planet and ourselves. It is a cancer that grows and overwhelms what lives and what doesn't. We must learn from Nature's simple elegance, from its esthetical and economical commitment to functionality and form (Gleiser, 2003)

On the other hand, Re-using, Re-manufacturing and Recycling practices are important to avoid the final disposal of valuable or harmful components as landfill. In addition to this philosophy of 4 Rs, a Green Manufacturing policy must consider regulatory compliance and employee healthy, and safety.

Major benefits are basically: cost reduction, energy and water conservation, minimization of overall output of waste, and in terms of financial, ecological and health costs. Moreover, it is also possible to identify new products and business opportunities through the use of wasted materials (Martin, 2001). Total Quality Environmental Management and Environmental Management Systems may play a very important role in the establishment, implementation and monitoring the environmental performance of manufacturing function.

2.3.5 Reverse logistics

Reverse Logistics is considered in many publications as part of green supply chain management but in this work it is treated as a separate tool from green supply chain practices. The main reason for this is because different skills and ways of thinking are needed to run a programme of Reverse Logistics. De Brito (2003) noted that traditional logistics uses “forward” thinking; nevertheless, product recovery approach is a vital condition for the future. Fleischmann et al. (1997) give some examples of how several countries have enforced environmental legislation, charging producers with responsibility for the whole product life cycle. Nevertheless, companies can make Reverse Logistics a profitable activity by recognising the value of some components in the products discarded at their end-of-life, by avoiding landfill costs or environmental liabilities because of fines. Shrivastava (1995) note that in some end-of-life items, such as used tyres, 95 percent of what is discarded as waste is usable energy. Similarly, discarded automobiles have many reusable components and materials, but they are simply scrapped because currently it is too expensive for them to be recovered. Thus, a set of criteria is needed to identify what can be reused. Fleischmann et al.

(1997) suggest a number of criteria based on (1) reuse motivation, (2) type of recovered items, (3) form of reuse, and (4) involved actors. In fact, Fleischmann et al. (2000) have identified that product recovery networks comprise the following functions: (1) collection; (2) inspection/separation; (3) re-processing; (4) disposal and, (5) re-distribution.

Dowlatshahi (2005) considers the strategic factors for Reverse Logistics, explaining the implications of costs, quality, customer services, environmental concerns and finally, political/legal concerns. For instance, does the cost of Reverse Logistics increases significantly the overall cost of the products? What are the costs of not doing it? How does an illegal action affect the company's image and financial performance? Moreover, is the customer keen to buy a product that has reused components? All of these questions show how Reverse Logistics must be addressed as a strategic weapon.

Therefore, a Reverse Logistics system should take into consideration the internal processes of an organisation. Better integration of vendors and after sales policies will be required. For example, most automakers have no contact with their product after the warranty services finish, so one strategy adopted by Toyota has been to extend the warranty time. As a result, customers feel more confident about their vehicles and Toyota is able to maintain in contact with them for a longer period of time in which can sell after-sales services.

Like other Green Operations practices, Reverse Logistics is also strongly influenced by the product design. The more product and process development include valuable components in their composition, the more Reverse Logistics can become a less cost-sensitive activity, i.e., the final disposal having a high value; reuse, remanufacture and recycle would become a viable alternative as they could pay off the costs of collecting, separating and treating scrap instead of buying new raw materials.

2.3.6 Innovation

Strongly advocated in management studies, innovation can be a powerful source of environmental improvements. In this thesis, innovation is understood from its classical roots (e.g. Schumpeter's studies, mainly Schumpeter, 1942), i.e, any invention (new product) brought to the market or changes on the companies' products, processes, and structure that leads to a higher firm performance or customer value. Porter and Linde (1995a) present cases where innovative companies used environmental pressures to both become more competitive and improve environmental performance. With similar results, Florida (1996) found a positive relationship between advanced manufacturing innovation and environmental performance of analysed companies. At supply chain level, Geffen and Rothenberg (2000) indicate that "*the most significant improvements in environmental performance were observed when innovative technology and open, flexible management approaches were coupled with supplier expertise*."

Thus, some innovations which may not be clearly linked to operations (innovative business models, for example) or seen as a deliberate 'green operations practice'. However, these types of interventions are capable of having significant positive impact on the environmental performance of operations function.

Table 2.1 shows the list of green operations practices (including innovation), their objectives, main benefits, and the activities of the operations function to which they are related.

Table 2.1 – Green Operations Practices, activities of the operations function, objectives, and main benefits (Nunes and Bennett, 2010)

Green Operations Practices	Activities of the operations Function	Objectives	Main Benefits	Related Literature
Green Building	Production capacity planning	Enhance environmental performance during construction and operation of an industrial plant considering sustainability of the production site, water and energy efficiency, resource and materials use, indoor environmental quality, and innovation and design process.	Higher worker productivity; Reduction in health and safety costs; Improvements in indoor environmental quality; Reduction in maintenance costs; Energy and water savings; Better waste management in construction and operations phase;	Paumgartten (2003) Ries *et al*. (2006) Elliot (2001)
Eco-Design or Design for environment	Product and process development	Consider the product's life-cycle in order to design more environmentally-friendly products and use environmentally sound processes	Enhancement of reusability, recyclability and remanufacturing possibilities; Reduction on the use of hazardous substances; First-mover advantages (royalties, access to green market niches, etc); Reduction of final disposal costs; Higher eco-efficiency and eco-effectiveness;	Mildenberger and Khare (2000) Kleindorfer (2005) Sarkis (1998) Boks (2006) Angell and Klassen (1999) Shrivastava (1995) Florida (1996)
Green Supply Chain	Supplier relationship and in-bound and out-bound logistics	Incorporate environmental criteria and concerns into organisational purchasing decisions and long-term relationship with suppliers	Sharing risks and pressures along the supply chain; Transfer of environmental technology and consequently waste and cost reduction in the suppliers' operations	Gilbert (2001) Angell and Klassen (1999) Kleindorfer et al (2005) Sarkis (1998) Zhu *et al* (2007)
Greener Manufacturing	Manufacturing (Production)	Increase efficiency continuously and integrate 4Rs' in the production: Reduce, Reuse, Remanufacture and Recycle	Better economic, environmental, social and economic performance through reduction of waste and therefore, costs.	Angell and Klassen (1999) Kleindorfer *et al* (2005) Sarkis (1998) Shrivastava (1995)
Reverse Logistics	Supplier relationship, logistics and after sales	Plan, implement and control backward flows during process and after use of finished goods, mainly to end-of-life products.	Reduction of environmental burdens on the final disposal; Reduction of landfill and environmental liability costs; (Re)use of valuable components of an end-of-life product.	De Brito (2003) Kleindorfer *et al* (2005) Shrivastava (1995) Fleischmann *et al* (1997)
Innovation	All activities and beyond operations including business model designs.	Improve goods and services and increase profitability,	Eliminate unnecessary processes, sources of pollution, waste, etc	Porter and Van Der Linde (1995a) Florida (1996)

2.4 Environmental Decision Making

Most of the studies in environmental decision making have been carried out at the policy level (English, 1999; Hoffman, 1999; Azapagic, 2003). In addition to the issues related to the relationship between drivers, pressures, decisions and environmental performance, this fact adds another gap in the literature related corporate and departmental-level strategic decisions. In fact, very little about the translation of environmental policy into environmental strategy, and finally, environmental decisions was researched. At company and departmental levels ISO 14001 structures have been used to take decisions although they do not include decision making methodologies. Current literature on the topic brings little to light about the particularities existing between environmental decisions in the different activities of operations function and technology choice. As policy is cascaded to business units and departments it becomes necessary to understand the different drivers and structures within them. Also the existing studies in the field are mostly quantitative, which leaves a gap to be explored regarding the processes behind environmental decision-making in manufacturing organisations (Presley, Meade, and Sarkis, 2007; Tsoulfas and Pappis, 2008; Staikos and Rahimifard, 2007).

As mentioned earlier, environmental decision making has been explained as developing environmental policies. For example, English (1999) offers an approach for information-gathering and analysis for environmental decision making, consisting of eight categories: (1) determine goals/values, (2) characterise the environment, (3) characterise the economic, social, political setting, (4) characterise the legal/regulatory setting, (5) integrate information, (6) forecast, (7) assess, refine, narrow options, (8) conduct post-decision assessment. Alternatively Hoffman (1999) presents a roadmap for organizational change to invoke environmental actions. The author designs four phases to encourage change: diagnosis, unfreezing, movement, refreezing. After 'diagnosing' concerning issues, the 'unfreezing' phase includes establishing a sense of urgency, the forming of a guiding coalition, and creating a vision. 'Movement' requires communication of the vision, empowering others to act, planning for and creating change, and consolidating improvements. Finally, 'refreezing' relates to institutionalizing new approaches. These approached are more change management.

The literature indicates that the external pressures and drivers are to be the trigger for developing environmental policies, strategies, and at last the adoption of green operations practices. Analysing the study carried by Hall (2000), who has listed environmental drivers, there is little evidence on how drivers will impact different departments where the decision is being made. For instance, customers are said to be an important source of pressure; but Green, Morton, and New (2000) argue that the view of customers as a primary agent of environmental change is inadequate, and there should be an effort to understand corporations and public organisations as consumers in order to push for a green economy. Furthermore, how important are customers as drivers for environmental changes in the product? Is there any difference between the pressures from legislation towards green processes from those related to green products? All these issues will ultimately impact on the environmental decision making. In addition, these studies on perception of the importance of different drivers draw attention to the complexity in the environmental decision making process, which may only be addressed by systems thinking approaches.

The use of systems thinking has been steadily growing in organisations (Senge, 1990; Checkland, 1981; Ison, Blackmore, Collins and Furniss, 2007; Kunsch, Theys, Brans, 2007) and there are opportunities for it to contribute to environmental decision making (Van Der Vorst 1999; Azapagic, 2003), especially operations and supply chain management.

Indeed, systems thinking approaches to environmental decision making have been taken. For example, Van Der Vorst (1999) highlights that a systems approach should extend beyond the environmental impact assessment, environmental management systems, and life-cycle assessment. Azapagic (2003) proposes a general five stage framework for Corporate Sustainability Management System, which is compatible with ISO 14000 environmental management systems standards. The five stages are: (1) sustainable development policy, (2) planning, (3) implementation, (4) communication, and (5) review and correction actions. Azapagic locates the business strategy and vision in the centre of the model linking it to sustainable development policy and planning stages.

Presley, Meade, and Sarkis (2007) notice that most models support sustainability decisions at a broader dimension, as such studies include regional policy and industrial analysis. Thus, they present a Strategic Sustainability Justification Methodology (SSJM) comprising four phases: (1) identify system impact, (2) estimate impact, (3) perform decision analysis, (4) track operations. The authors test this in a reverse logistic outsourcing example including economic, social and environmental dimensions.

Also on environmental decision making in supply chains, Tsoulfas and Pappis (2008) used a multi-criteria decision-making (MCDM) technique to include environmental performance indicators in the analysis of supply chains. They chose MCDM to analyse objectives and criteria that were conflicting, multi-dimensional, incomparable and incommensurable and needed to accommodate quantitative and qualitative data. Another multi-criteria approach is presented by Staikos and Rahimifard (2007) who combined Analytical Hierarchy Process (AHP) with life-cycle and cost benefit analysis to analyse shoe waste management. The authors used quantitative (for economic and environmental factors) and qualitative (for technical factors) analyses for a complex range of alternatives: (1) reuse: shoes are reused in less-developed countries; (2) recycling: shoes are shred as a whole; (3) recycling: shoes are dissembled to shred separated materials, (4) recover: incineration to generate heat and electricity; (5) disposal: in a landfill. This example shows a range of alternatives that make environmental decision making more complex.

Indeed, supply chains have been studied to bring business sustainability into a broader arena. On supply chain design, Tsoulfas and Pappis (2006) classify environmental principles into six categories: (1) product design, (2) packaging, (3) collection/transportation, (4) recycling/disposal, (5) greening internal/external business environment, (6) other management issues. Thus, supply chain design stretches the scope of environmental analysis, increasing its complexity and uncertainty and other business trends (e.g. market globalisation, offshoring, outsourcing, etc) that bring other complexities to evaluate/manage business performance (Hill, 2007; Friedmand, 2006).

This is daunting for the management of supply chains given the high number of players and strong trade-offs. Consequently, while questions of *why* a company should implement sustainable supply chain practices may have been addressed; other issues remain (e.g. how companies make environmental decisions or how to select environmental technologies). There are indeed previous studies on methodologies to optimise strategic investments, guidelines to the implementation of environmental initiatives, the importance of aligning environmental objectives with corporate goals; nevertheless, empirical evidence needs further investigation, mainly for strategic decisions in greening operations.

The complexity of environmental decisions is given due to its nature. While some business practices return profits, environmental protection is recognised more as a public good (Orsato, 2006) which may not return profits but may conflict with corporate objectives under an opportunity cost analysis. This extends to the public good created by the supply chain. As Seuring and Müller (2008) have identified, the two objectives of corporations for greening supply chains are: (1) supplier management for risks and performance (e.g. avoiding risk from suppliers with poor environmental and social performance); (2) supply chain management for sustainable products as a more proactive strategy. However, as businesses consider the importance of managing (and their suppliers') intangibles, environmental issues may become more valuable. Following this trend, environmental/green operations management has gained special attention and, due to the complexity of issues and range of resolutions, a systemic approach seems necessary to analyse how decisions impact on environmental aspects and the business/operations strategy. In fact, authors have already claimed the need for a systems view of environmental issues (Corbett and Klassen, 2006; Klassen, 2001; Graedel and Allenby, 1995, Kleindorfer et al, 2005; Orsato, 2006).

The extended view of environmental management towards supply chain is justifiable given the transfer of environmental impacts within outsourcing practices and the different legislations in countries (Brown, 2008). This refers again to the point made by Child and Tsai (2004) about companies that face different institutional constraints in different countries and how that affects their environmental strategy. In fact, the environmental strategy need to be seen as supportive to business strategy, just as operations, marketing, and finance strategies are. Within this philosophy, van Hoek (2002) discusses the integration of environmental issues and business strategy, affirming that it should not be an add-on characteristic but a strategic choice that has to be managed consistently and accordingly. Van Hoek adds the importance of market willingness to pay for the green product and other market issues e.g. barriers to imitation, and by adding new criteria to assess greening alternatives, we increase the decision complexity.

In the 1990s, when the scope of environmental decisions was more narrowed within only manufacturing processes, many authors published seminal studies to show that environmental decisions towards pollution prevention technologies were superior, as well as better aligned with business goals, than pollution control technologies (Klassen and Whybark, 1999; Sarkis, 1995; Shirivastava, 1995; Beamon, 1999).

However, a crucial issue remains unexplained – how do the drivers impact on the implementation of green operations practices? Zhu et al (2005) has investigated several manufacturing sectors and concluded that the existence of environmental pressures and drivers was not well correlated to the implementation of green supply chain practices. Although correlated to environmental and operational performance, the adoption of green supply chain practices has not improved economic performance (Zhu et al, 2005). Zhu et al (2007) replicated this analysis for the automotive industry in China. The results show an intriguing situation:

> "The Green Supply Chain Management pressures/drivers seem to have no significant impact on the Green Supply Chain Management practices with respect to internal environmental management practices, green purchasing, customer cooperation and eco-design" (Zhu at al, 2007).

Zhu et al (2007) have also found difficult to connect the practices to overall performance since some practices may have a positive impact on environmental performance but no significant impact on operational performance for instance.

Given these complexities and economic, social and natural contexts in which companies operate, we have studied the main drivers for environmental decision making, the origin of ideas for environmental improvement, performance measurement, and the structures used for environmental decision making.

Moreover, as the pressures are not only focused on manufacturing processes anymore, complexity of environmental decision making and performance measurement is added. Figure 2.3 shows decisions levels when greening operations in supply chains. The practices in decision level 2 emerged from the literature, allowing a classification of environmental practices. The further development of this classification has lead to the green operations framework (Figure 8.1)

The importance of figure 2.3 resides in setting a scope and understanding that environmental decisions can take place at various levels: corporate strategy, operations strategy, product and process development and improvement, amongst other areas of operations (facilities, supplier relationship, logistics, etc).

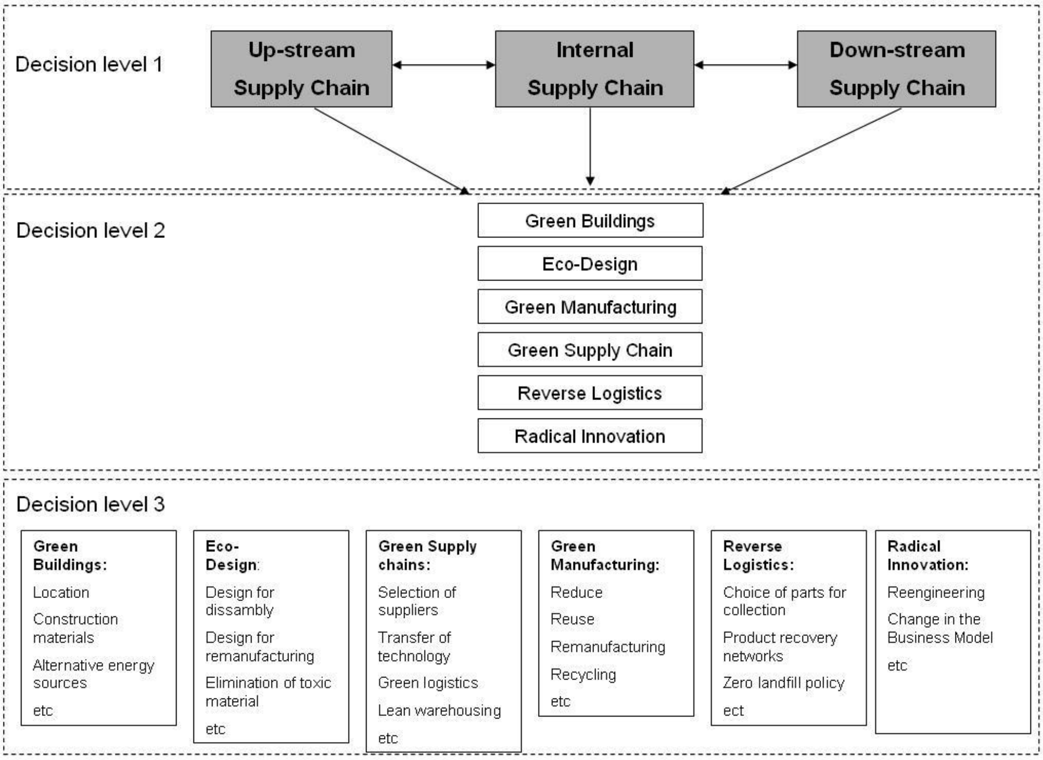

Figure 2.3 – Decision levels in greening operations and supply chains

Decision level 1 shows the need for the company to identify its high-level priorities for environmental strategies i.e. greening internal operations, its supply chain towards suppliers (up-stream) or customers (down-stream), or some combination. The second level includes choosing green operations practices to be implemented. Note there is one green operation practice for each operations function: green buildings (facilities), eco-design (product development), green supply chain (supplier relationship, inbound and outbound logistics), green manufacturing (production), reverse logistics (backwards flow in the supply chain, including product recovery). Innovation represents changes at business or production systems level (new business models, modularisation of production, etc) that can lead to significant environmental benefits. Hence, environmental performance of facilities could be improved by implementing green building techniques; product performance through eco-design, and so on. In decision levels 1 and 2, alternatives are not necessarily mutually exclusive; nevertheless prioritisation (of time, capital, and other resources) may be necessary.

Although Figure 2.3 shows the decision level 3 as the lowest level, we can cascade alternatives in more levels. The intention behind showing three levels is to demonstrate how pressures force decision makers to choose first specific activities in the supply chain or green operations practices in order to meet different pressures. However, the interaction of issues is not reflected in this decision structure so it was necessary to develop a systems approach.

Next, the automotive industry and the environment is examined, where the sustainability issues are discussed within this sector.

2.5 The automotive industry and the environment

This section presents an overview about the automotive sector and develops the arguments of the current unsustainable context of automobile production. As presented in the Introduction Chapter, the transportation sector is a significant contributor for urban air pollution as well as green house gases emissions, particularly, CO_2 (Figures 1.5 and 1.7). Road transportation is the main modal in terms of pollution, being cars the most important sources of emissions as shown in Figures 1.8 and 1.9.

A recent work led by Professor Julia King entitled “The King Review of Low Carbon Cars” has discussed the potential for CO_2 reduction in transportation (Part I) (King, 2007) and provided recommendation for action (Part II) (King, 2008). The recommendations made by King (2007) concentrate on four grand areas: reducing vehicle emissions; use of cleaner fuels, influence consumer choices; and research and development. Because car useage is responsible for 85% of the total emissions through the life-cycle of a vehicle, most of the recommendations are product-oriented.

Nevertheless, the emissions from manufacturing activities, although accounting for only 10% of the total, are critical for environmental performance of car companies as they need to maintain emissions below city council’s emission limits. If council’s emission limits are not met, the manufacturing plant may be fined or even ordered to stop production. Likewise, the disposal of cars is responsible for 5% of the total life-cycle emissions; however, there are serious environmental impacts mostly related to soil contamination. Therefore, environmental decisions in the end-of-life cars are important to avoid environmental fines or even stoppage of vehicle production.

By the end of this section, the complexity of achieving economic, social and environmental sustainability in the automotive sector will become clear, as well as the difficulties for environmental decision making, mainly at strategic level.

2.5.1 Overview of the automotive sector

The automobile industry had small radical changes over the last 30 years. However, those changes were remarkable and had a significant impact on practice and also on academia. The Toyota Production System – Just in Time and the modular consortium are the latest innovations from the production system perspective. Transfer of the assembly plants to developing countries and global outsourcing are evident changes in the business and operations strategy. These changes were insufficient to make the sector more sustainable. As an evidence of this, the automobile industry is still struggling against high break-even points and environmental and social challenges. Strong dependence on fossil fuels and large consumption of raw material lead the environmental problems.

The automobile industry is said to be the largest manufacturing sector in the World and is one of the most resource-intensive of all major industrial systems (Mildenberger and Khare, 2000). According to the 2006 annual report of *Associação Nacional dos Fabricantes de Veículos Automotores* – ANFAVEA, a Brazilian Association of Car Manufacturers, World vehicle production was 64,272,000 in 2004 and the World fleet had 837,184,000 vehicles in 2003. In developed countries such as the USA, Italy, Japan, Germany, France and UK, the ownership rate of vehicle per 100 head of total population is higher than 55 (Anfavea, 2006). The highest rate is in United States, where there are 76.92 cars per 100 persons (see Table 2.2).

Table 2.2 – Cars per 100 heads of population from 1994 to 2003 (Adapted from ANFAVEA, 2006)

Countries	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
USA	76.92	76.92	76.92	76.92	76.92	76.92	83.33	83.33	83.33	76.92
Italy	55.56	58.82	58.82	58.82	58.82	62.50	62.50	62.50	66.67	66.67
Australia	58.82	58.82	58.82	58.82	62.50	66.67	66.67	52.63	62.50	62.50
Japan	52.63	52.63	55.56	55.56	55.56	55.56	58.82	58.82	58.82	58.82
Germany	52.63	52.63	52.63	55.56	55.56	55.56	58.82	58.82	58.82	58.82
France	52.63	52.63	52.63	55.56	55.56	55.56	58.82	58.82	58.82	58.82
Canada	62.50	58.82	58.82	58.82	58.82	58.82	55.56	58.82	58.82	58.82
Spain	41.67	43.48	45.45	47.62	50.00	52.63	55.56	55.56	58.82	58.82
UK	47.62	47.62	47.62	50.00	52.63	52.63	52.63	55.56	55.56	55.56
Austria	52.63	50.00	55.56	52.63	52.63	52.63	55.56	55.56	52.63	55.56
Belgium	45.45	47.62	47.62	47.62	50.00	50.00	50.00	52.63	52.63	52.63
Sweden	45.45	45.45	45.45	45.45	47.62	47.62	50.00	50.00	50.00	50.00
Czech Republic	27.78	33.33	31.25	38.46	40.00	37.04	41.67	41.67	40.00	40.00
Poland	20.41	26.32	23.26	23.26	23.26	23.26	28.57	28.57	33.33	34.48
South Korea	16.39	19.23	20.83	23.26	22.73	23.81	23.81	27.78	29.41	30.30
Mexico	13.33	13.33	12.66	13.51	14.29	14.71	15.15	16.39	18.18	18.18
Argentina	16.67	16.95	17.24	17.54	18.18	18.18	18.87	18.87	18.18	18.18
Brazil	9.62	9.71	10.64	10.99	11.11	11.24	11.36	11.63	11.90	11.90

As shown in more recent reports available by ANFAVEA (visit: www.anfavea.com.br), it is expected that developing countries, mainly those which are growing faster in the 21st century and with large populations such as China, India, Indonesia, Brazil, and Russia, will tend to increase their rates of cars per head of population to numbers similar to developed countries. The fast growth of vehicle ownership in developing countries indicate that in 20 to 30 years, a country like Brazil could reach a car ownership rate similar to Germany and UK. In 2050, Brazil will possibly overtake the USA with a car ownership rate of 645 cars per inhabitant (King, 2007).

In late 2007, the World's financial crisis strongly affected sales and production of automobiles in several developed countries, As a result, China overtook the USA in the registration of new vehicles in 2009. The Chinese authorities registered 13.6 million new vehicles against 10.6 million in the US (Anfavea, 2010). Although total vehicle production worldwide fell in 12.8% in 2009, after falling 3.7% in 2008; China's production grew 48.3% in 2009 subsequent to a growth of 4.7% in 2008. India grew 12.9% in 2009 and 3.5% in 2008, while Brazil had an 8% growth in 2008, after experiencing a slump in production by 1% in 2008.

Even though the production of vehicles offers significant enjoyment and the use of cars increases substantially personal mobility and productivity; there are various negative implications for the environment that occurred in developed countries and are being replicated in the developing countries. These are: air pollution in urban centres, road congestions, etc. In fact, because some developing countries have a less effective environmental regulation and lack of infra-structure, the impact of automobile use is somewhat greater than in developed countries. Linfen (in China), where automobiles are said to be the main source of pollution, was considered one of the World's most polluted city. The World Bank has reported that 16 of the 20 most polluted cities in the world are Chinese (TIME, 2007).

According to Forbes (2006), the cities with the highest level of population congestion are: Manila, the Philippines; Cairo, Egypt; Lagos, Nigeria; Macau, off the Chinese coast; Seoul, South Korea; Dhaka, Bangladesh; Buenos Aires, Argentina; Jakarta, Indonesia; Kaohsiung, Taiwan; and Santo Domingo, the Dominican Republic.

The more the impact of auto industry become evident, the greater the need for changes in the sector and its products.

Pursuing changes in this industry is in fact complicated due to its economic and social influence. Indeed, the impact of the automotive sector on a nation's economy is significant regardless of whether it is an emerging or developed country. For example in 2002, China had 33.5 million people employed (one out of 22) in the automotive industry and directly related sectors (Zhu, Sarkis and Lai, 2006). In the USA, the Alliance of Automobile Manufacturers claims that 1 out of every 10 jobs is dependent on the automotive industry (new vehicle production, sales and other related jobs) (Alliance of Automobile Manufacturers, 2007).

In 2006, when this study was initiated, the production of motor vehicles was led by General Motors (GM), Toyota, Ford, Volkswagen and Honda. GM produced 8,926,160 vehicles in 2006; Toyota reached 8,036,010 and Ford, 6,268,193 in the same year according to the international organization of motor vehicle manufacturers (OICA, 2007).

Table 2.3 shows the World's 10 largest auto producers from 2000 to 2004. These numbers will tend to change in the next years, mainly, due to the economic growth of China, India, Russia and Brazil. For instance, latest statistics show that Japan took the lead from USA and China overtook the 3rd position from Germany in 2006 (OICA, 2007). The International Organization of Motor Vehicle Manufacturers provides on its website (oica.net) more up-to-dated statistics about the vehicle fleets worldwide.

Table 2.3 - The World’s 10 largest Auto Manufacturing Countries from 2000 to 2004 (thousands of units) (Anfavea, 2006)

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Figure 2.4 shows the World’s 10 largest vehicle fleets. Recalling Table 2.2, one will see that developed countries have higher rates of cars per head of population than developing ones. It is possible to expect in the near future a significant increase in the vehicle fleet of China, India, Russia and Brazil amongst other developing countries when they reach higher levels of economic growth. Due to specific conditions for production and strengthening of their internal markets, these countries will tend to increase production, their vehicle fleets, and consequently, their rates of cars per inhabitant.

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Figure 2.4 – The 10 World's largest vehicle fleets (Million units) (Anfavea, 2006)

Moreover, new players have already also emerged to revolutionise car production in the 21st century. In an interview with a Brazilian magazine, VEJA, the Renault-Nissan CEO Carlos Ghosn admits the risks to the traditional companies in the sector considering that India and China intend to produce low-cost cars (VEJA, 2007). Indeed, a USD 2,000 car by the Indian group Tata Motors is already available. The Tata Nano is basically composed of plastics and have a high fuel economy to respond to the needs of the popular market for low operating costs during the use.

In addition to the changes in the automotive industry, the Brazilian market has become the testing ground for global automakers and serves as the base for new projects targeting emerging markets. Brazil has also been used to experiment with production and design strategies based on modular concepts, mainly in production (Baldwin and Clark, 1997). Modular production/supply systems tested in Brazil have been at the centre of the discussions about "transplanting" new models of production systems to traditional industrialised countries, such as in the GM case and its so called

"Yellowstone project"; in Ford's plans for modular assembly of the Focus and in Fiat's Amazon project for renewal of the Punto etc (Salerno and Dias, 2002).

A different type of modularisation, from the one tested in Brazil, appears in the literature. Dower (2006) presents a modular vehicle, the Ridek, composed of a motorised deck (the Modek) with a passenger compartment (the Ridon) riding upon it.

Wells and Nieuwenhuis (2006) explore five examples of relocalisation through the concept of Micro-Factory Retailing (MFR): Th!nk, Ridek, Oscar, MDI Air Car and GM AUTOnomy. The MFR concept is based on the claim that it would be more profitable, environmentally-friendly and socially responsible to have many small factories rather than a large manufacturing plant. The MFR would also be responsible for commercialisation and maintenance in order to increase profit margins. Wells and Orsato (2005) provide a preliminary comparison of the benefits between centralised (large manufacturing plants) and decentralised (MFR) business models such as such as reduction of break-even point, better work environment and the use of alternative material (e.g. carbon fiber) and fuel system (e.g electricity, fuel cells).

A number of companies have started considering environmental concerns within their new product development strategies in late 1990s. Mildenberger and Khare (2000) reviewed existing tools and opportunities for reducing environmental impacts in the automobile industry and during the car life cycle. Their paper includes an example from the German company Daimler-Benz and its SMART car, which was the winner of the 1998 ecology check. Another well-known example is Toyota with the Prius launched in 1997. Even more notable is the new Brazilian Company, Obvio, which, since its conception, has had a full-commitment to sustainability. Its projects are being developed through a carbon neutral standards programme, not only for the car, with assistance from Lotus Engineering, but also including facilities, landscape, transportation structure, social and economical regional environment (Obvio, 2007).

These cars (Prius, Smart and Obvio) provide evidence that a new green market niche is already developing. Nevertheless, due to its importance and size, the automotive industry is a cauldron of complexity and the decisions within the sector involve great risks. The King Report analyses the technical challenges for infrastructure and vehicle technology for the introduction of alternative fuels (King, 2007).

2.5.2 Sustainability issues for car manufacturers

The benefits of cars are clear: they provide a door-to-door transportation system, the means to gaining access to life’s necessities and employment, and a source of pleasure and social status. However, despite these benefits there are environmental burdens as well: local air pollution, greenhouse gas emissions, road congestion, noise, mortality and morbidity from accidents, and loss of open space to roads, car parks and urban sprawl (Vergragt and Brown, 2007).

The modular system used by Volkswagen, General Motors and Ford is, besides simplifying the final product and transferring the competence and responsibility of manufacturing components to suppliers, aimed at lowering inventory levels (or even no stock), zero-waste philosophy and high integration of suppliers (keiretsu), i.e., all of these are considered a heritage from JIT (Parente, 2003). Besides the lean thinking, one of the most significant developments in the automobile industry in recent years has been the changing relationship between the major vehicle producers and their component suppliers (Dicken, 2003).

Baldwin and Clark (2000) define a module "as a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units". A modular system is composed of units (or modules) that could designed separately (with a relative higher level of independence) but still function as an integrated whole (Baldwin and Clark, 1997). Defining what is a module as opposed to a system is far from an exact science, as the words are often used interchangeably. Collins et al (1997), who provide the following definitions that have been adapted from Mckinsey: a *module* is a physical subassembly – e.g. seats, dashboard/cockpit and front-end assemblies, while a *system* is a functional aggregate of components not necessarily delivered as one physical unit – e.g. braking system.

Sanchez (2004) describes how modular platforms can actually transform businesses. For Sanchez, firms successfully pursuing platform-driven strategies have learned that platforms are a powerful design approach that requires clarity, definition, and discipline—as well as creativity—in conceiving strategically focused and carefully coordinated modular product and process architectures. In fact, modular architectures are far beyond than only product development, and its application in other processes may result in increased flexibility for the company (Sanchez and Mahoney, 1996). Arnheiter and Harren (2005) cites the automobile as a classical example that makes use of all four types of modularity, e.g., the previous examples from manufacturing modules (seats, engines, panels, etc); the brake pads as limited life modules; a luggage box as an example of product-use modules; and the chip controlling the fuel injection is in most cases a data access module. Latest research on the topic have suggested that mass customization in terms of product variety and flexibility is easier achieved through modular architectures (Mikkola, 2007; Mikkola, 2006). Nunes and Bennett

(2008) have discussed how modularity can contribute to the implementation of green operations. In all types of modularity, product simplification through the use of modules might enhance environmental performance and facilitate further activities such as maintenance and repair contributing to a long life of cars on the road. Moreover, modules will make automobiles easier to disassembly increasing the chances of reuse of valuable components and a better final disposal of scraps.

Also, the transfer of the assembly plants to developing countries and global outsourcing are evident changes in the industry's business and operations strategy. Nevertheless, these changes have been insufficient to make the sector more sustainable. As evidence of this the automotive industry is still struggling against economic, environmental and social challenges. Orsato and Wells (2007) point out the many economic challenges currently facing the industry: notably over-capacity; saturated and fragmenting markets; capital intensity; and persistent problems with achieving adequate profitability. Strong dependence on fossil fuels and large consumption of raw material lead the environmental problems. As a result, in a near future, it is expected that the sector will face strong pressures and take initiatives in order to reduce the environmental burdens from car use and its production process.

Hoffman (1999) highlights the importance of preparing the organisation for change. He explains that a crisis or organisational jolt may motivate companies to address the necessary changes and in fact says that the first step to accomplish successful change in an organisation is to "establish a sense of urgency".

For the automotive industry, the "sense of urgency" has become clearer since Brazil, Russia, India and China (BRIC countries) entered the league of big consumers. Road transportation is strongly dependent on basically one type of energy (fossil fuels) and is responsible for 57% of World's oil consumption (IEA, 2005). The increase of transportation in the BRIC countries will increase consumption, and therefore oil prices, affecting personal mobility worldwide. Moreover, improving efficiency of engines to gain high fuel economy will not solve completely the problem because the number of cars and their power are steadily growing.

Corroborating with this hypothesis, Zhao (2004) claims that the rapid and continuous growth of China's vehicle population has also brought great challenges to China's energy resource security. He highlights that if China's vehicles per capita were the same as the USA, the oil demand in China would exceed worldwide production by 18%.

Regarding car use, Wells (2007) discusses the automobility culture in emerging economies and the numbers of deaths and injuries resulting from road traffic accidents. In total, since motorisation was started there have been more than 30 million deaths attributable to road accidents, more than all the soldiers in the two World Wars combined.

Dixon, Scura, Carpenter and Sherman (1994) evaluate the economic damage from specific environmental impacts. For example, to value the damage due to air pollution, he calculates the cost of lost work days, medical expenses, cleaning costs and, losses of value in properties. Indeed, pollution control regulations tend to see transportation as a target. As vehicles are responsible for one quarter of total green house gases emissions (Sperling, 2000), a stricter regulation for cleaner cars is expected as well. In the USA some initiatives are already taking place in California, which is leading a process to have a zero-emission fleet on the road (Greene, 2001).

The automobile industry has indeed made remarkable positive contributions to the world economy and people's mobility, but its products and processes are a significant source of environmental impact. To better understand the relationship between the automotive industry and the environment, Table 2.4 'Environmental Aspects and Impacts of the Automotive Industry' shows the main environmental aspects and impacts of the activities in this industry, together with a basic assessment based on the suggestions of ISO 14004:2004 'Environmental management systems -- General guidelines on principles, systems and support techniques' (ISO, 2004).

Table 2.4 – Environmental Aspects and Impacts of the Automotive Industry (Nunes and Bennett, 2010)

Aston University

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Total world production of cars reached more than 53 million units in 2007 and if commercial vehicles are incorporated this increases to 73.10 million units (OICA, 2007). The top countries in terms of production are Japan, USA, China, Germany and South Korea. In 2008, the largest global manufacturers were General Motors, Toyota, Ford, Volkswagen and Honda. If only passenger cars are considered then Toyota is the largest producer, followed by General Motors and Volkswagen. There are approximately three quarters of a billion cars worldwide and, if the industry continues to produce cars at the current rate, there will be two billions cars on the road by 2050 (Toyota, 2007a).

Katayama and Bennett (1996) have anticipated the challenges of cost competition and the vicious cycle in which manufacturers, including automobile companies, have been drawn. A strong focus on lean production has created a cost decrease leading to price reduction, and thereby market saturation and predatory price competition with low profit margins. Katayama and Bennett (1996) argue that companies, in particular those in Japan, cannot rely any further on the benefits of lean production alone, as the rules of competition changed from the 1980s to the 1990s. In fact, in the 21st century the rules are changing again and there is increasing pressure for the adoption of environmentally-friendly processes and greener products. Environmental concerns must go beyond mere efficiency gains. In fact Wackernagel and Rees (1996) say that encouraging efficiency leads to increasing consumption, which increases the overall use of resources. “Indeed, in spite of efficiency gains, most industrial countries’ total energy has increased in recent years … Moreover, in practice, efficiency gains and current incentives often work directly or indirectly against resource conservation” (Wackernagel and Rees, 1996). The ironic effects of the environmental gains from efficiency and continuous improvement are shown in Figure 2.5.

Figure 2.5 – The increase in overall environmental impact due to efficiency gains (developed by the author)

Figure 2.5 shows how efficiency gains will result in a reduction of unitary production cost allowing companies to push market price down. This is most true to companies competing through price. Firms competing on differentiator factors may prefer to keep profit margins higher keeping the market price the same regardless efficiency gains. Lower price will consequently increase consumption unless the goods have a very low price-elasticity, which is not the case for most of consumables today. When the overall consumption increases, more pressure is put on natural resources, more waste is created, and eventually, the environmental impact of societies will be bigger.

For the automotive industry, the major global impacts result after production from vehicle use (Mildenberger and Khare, 2000). However, there are also serious environmental concerns about the production and final disposal of cars. The use of the automobiles consumes a significant amount of fossil fuels, and therefore is an important source of pollution. The harmful substances in the car's exhaust emissions include carbon dioxide, carbon monoxide, sulphur and nitrogen oxides, particulate material, ozone, aldehyde compounds and hydrocarbon particles. During a car's production, the main negative environmental impacts result from solid waste generation, emission of Volatic Organic Compounds (VOCs), and high levels of energy and water consumption. In addition, at the end-of-life cars may contaminate the soil and aquifers if there is irresponsible final disposal and inadequate management of landfill sites. In addition, environmental impacts of car use continue to be often neglected, i.e. traffic congestion and accidents. Traffic congestion is a result of having a larger fleet than the road infrastructure can cope with. It reduces the "utility" of the car once it slows personal mobility and creates difficulties in driving the car (e.g. identifying parking spaces). Wells (2007) identifies traffic accidents as another important issue regarding car use, referring to the increasing number of fatalities among accident victims in developing countries, which comprise the major emerging market for automotive companies.

The interaction between design, production, use and disposal of cars brings also greater complexity and difficulties in taking environmental decisions. For example, reducing the weight of cars is one of the techniques to reduce fuel consumption during use. This is usually done by substituting plastics, aluminium and composites for steel in cars. However, this technique makes disassembly more difficult, and therefore negatively affects the recycling of end-of-life vehicles (Van Hoek, 2002). Similarly, the use of Just-in-Time practices may improve environmental performance in manufacturing, but it can increase the energy used in logistics due to more frequent deliveries (Zhu and Sarkis, 2004; King and Lenox, 2001).

Within a broader approach, Orsato and Wells (2007) summarise the context of the environmental, economic and operational challenges for the automotive industry. They explain that because carmakers are locked into three technological paradigms (all-steel car bodies, internal combustion engines, and multi-purpose vehicles), these companies tend to favour incremental improvements. In addition, the existing economic and political interdependency between this industry and other sectors (e.g. the oil industry) makes radical changes towards higher levels of environmental performance more difficult due to its complexity and extension. These issues concerning infrastructure, economical relevance and interdependence affect strongly the sustainability of the sector. Williams (2007) seeks a deeper understanding of sustainable mobility through a systemic view of not only operational issues; but at the level of business model (car ownership and product-service systems). Alongside their efforts, car manufacturers must confront a difficult reality; customers seem to be willing to drive greener cars, but green features play a minimal role in their purchasing decisions (Lane and Potter, 2007).

There are previous studies concerning benchmarking of automotive companies for environmental issues. Rothenberg et al (2005) suggest an approach to environmental benchmarking for automakers involving four categories: regulatory compliance, gross emissions, efficiency and life-cycle analysis. Hahn et al (2008) assessed 16 automotive companies (groups) based upon the sustainable value methodology. Their results show the Toyota and BMW groups as leaders and ahead of other competitors.

Zhu et al (2007) evaluate the pressures, practices and performance of green supply chains in the Chinese automotive industry. They use a comprehensive list of performance measures including economic and environmental indicators. Koplin et al (2007) also bring an extensive list of measures in order to introduce sustainability criteria in supply chain management. They use Volkswagen Group as a case in order to illustrate how supply policy can be cascaded into a various strategic, tactical and operational measures. Gernuks et al (2007) assess the environmental aspects of operations activities in Volkswagen to understand the contribution of production site, body shop, paint shop, assembly line, and logistic to the use of resources, waste, emissions, energy and water utilisation, and other environmental aspects. Hervani et al (2005) discuss the challenges of green supply chain performance measurement. A number of tools are presented including an environmental balanced scorecard.

Among the various approaches for benchmarking, the environmental performance of car manufacturers can be noted a strong link to environmental operations performance – total emissions, emissions per car, waste, etc – with little or no integration with product use or disposal, and what has been done to achieve such performance. Although it is quite valid to assess the current environmental performance of production it does not encapsulate the environmental performance of a car manufacturer in a strategic way based on the practices they are adopting and their intentions towards a more sustainable future.

A novel approach suggested by Stonebraker et al (2009), which includes an analysis of the supply chain fragility, uses a complete range of environmental and socio-economic factors. A broad analysis for environmental issues was also used by Oltra and Jean (2009a). They have shown how environmental innovations may be dependent on policy or regulatory push-pulls, technological regimes and market demands.

However, adopting a different approach from benchmarking environmental operations performance is also possible. Oltra and Jean (2009b) have researched the diversity of engine technologies for low emissions vehicles. Their study is focused on an analysis of patent portfolios of car manufacturers. Likewise, this thesis did not include in its scope the comparison of environmental performance, but only partially covered the way environmental performance is measured. Instead, environmental initiatives were examined rather than actual environmental performance. The benchmarking of initiatives is important because, when used alongside performance benchmarks, they may reveal best practices to excel in the different activities of the operations function.

2.6 Chapter Summary

Chapter two presents the literature review that is relevant to this thesis. Four main topics are discussed, namely: business sustainability, green operations, environmental decision making in the context of systems thinking, and an overview of the automotive industry in the world.

While in the previous chapter, the business sustainability introduction aimed at showing the relevance of the automotive industry and the emerging pressures on companies to cut carbon emissions amongst other reasons; the section in this Chapter two has shown how management studies had perceived the drivers, indicated strategic paths including link between environmental and firms' performance.

The topic of green operations is first introduced in Chapter two. The current concepts are presented alongside five major green operations practices: green buildings, eco-design, green supply chains, green manufacturing, and reverse logistics. Under the theoretical lenses of environmental strategy, the contribution of innovation in greening operations is also considered.

The classification of green operations practices that emerged from literature reveals the complexity of taking environmental decisions across the operations function. Nonetheless, the environmental decision making literature shows that most of the studies are linked to policy making. There is a gap with regard to the green operations strategy in the environmental decision making studies as most of the current investigations look are tactical or operational decisions. Multi-criteria decision making is the most used methods in solving these problems.

The overview of the automotive industry makes known the struggle of car manufacturers in reducing their overall environmental impact while growing their business. The increasing number of cars on the road creates a pressure on the energy systems and accentuates the problems of urban air pollution and emissions of CO_2. The environmental regulations are starting to enter in the market and car companies that do not have a clear environmental strategy may put their existence in risk.

The main gaps in the literature refer to (i) the link between drivers, decisions, and performance, and (ii) the environmental decision making process at firm or department level.

Indeed, an investigation needs to include a methodological approach that is appropriate to the chosen research problem as the decision on a specific research design will impact on the investigation outcomes. The next chapter will deal with these methodological aspects of this PhD investigation.

Chapter 3 - Methodology

This chapter refers to the research methodology of this thesis. It includes a brief background on philosophy of science and management research. It explains the philosophical position of this investigation and the role of the researcher, the reasons for choosing the qualitative methodology and the methods for data collection relevant to each research question. It also includes the logic behind the research phases comprising this PhD study.

3.1 Background on the Philosophy of Science

The Philosophy of science deals with the fundamental questions for scientific research. It is concerned with the issues related to the foundations of science, the formation of assumptions, use of methods, and lately, the ethical implication of scientific discoveries. The Encyclopaedia Britannica Online defines Philosophy of Science as:

> “ The Branch of philosophy that attempts to elucidate the nature of scientific inquiry—observational procedures, patterns of argument, methods of representation and calculation, metaphysical presuppositions—and evaluate the grounds of their validity from the points of view of epistemology, formal logic, scientific method, and metaphysics” (Kitcher, 2010).

The fundamental question in Philosophy of Science is “What is reality made of?” (Lee and Lings, 2008). From this primary enquiry, the schools of thought in science have developed their axioms, theories, research methodology strategies, and investigation methods. The perception of what reality and knowledge are had a profound impact on the output of knowledge generation processes. Four different concepts emerged on the basis of philosophy of science, namely: ontology, epistemology, axiology, and methodology. Failure to think through these concepts and other philosophy of science issues, while not necessarily fatal, can seriously affect the quality of management research because they are central to the notion of research design (Easterby-Smith, Thorpe and Lowe, 2001).

Lee and Lings (2008) discuss practical issues of applied business research in terms of philosophical concepts. According to the authors, ontology is the study of the nature of reality. It refers to how objective or independent reality can be in reference to an observer or participant in an event. The construction of reality is an essential issue for research ontology.

Epistemology follows ontology, since it is the study of what we can know about reality. While ontology is concerned to the nature of reality, epistemology studies the origin, nature and limits of human knowledge (Martinich and Stroll, 2010). An epistemic analysis then would discuss “how valid is the knowledge created?”, whether it is generalisable or not, or specific to a particular time and place (Lee and Lings, 2008).

Axiology is another important concept within the theoretical debate in Philosophy of Science. From Greek *axios,* “worthy”; and *logos,* “science”, axiology refers to the philosophical study of goodness or value (Encyclopaedia Britannica Online, 2010). Lee and Lings (2008) say axiology is in essence about the aims of research – and in its relation to ontology, it should consider the intentions of a researcher to explain, predict or understand reality.

Last but not least, methodology refers to how the research will be conducted in order to create original and relevant knowledge. It can be defined as a combination of techniques used to enquire into a specific situation (Easterby-Smith, Thorpe and Jackson, 2008). It can be quantitative or qualitative. The combination of quantitative and qualitative methods in a mixed approach is also used when a research question requires different approaches to be answered.

Under a philosophical debate, two main schools of thought have composed the extreme sides according to their ontological views of the world and knowledge: positivism and constructivism. Easterby-Smith, Thorpe and Lowe (2002) summarises the main characteristics of both approaches. A positivist approach will consider the reality objective where facts are concrete. The researcher remains detached, and therefore an objective viewer of the research problem to avoid bias on the (usually large) sample; aiming to explain the events through the demonstration of causality. On the other hand, constructivism considers reality to be subjective and ‘constructed’ by participants and observers of an event. The intentions are primarily to understand a given event and its complexity, usually by being part of a contemporary context. The choice of the sample can be justified using specific reasons (e.g. unique nature of an organisation), whilst positivist approaches will tend to randomly select participants to avoid bias.

3.2 Research Paradigm of Studies on Sustainability of Auto Industry

This section explains the dominant theory and paradigm on the subject of sustainability of the automobile industry. It also discusses alternative approaches that could be used for this research problem and evaluates qualitative and quantitative research designs to investigate the sustainability issues in that sector.

A literature review on the topic of sustainability of the automotive sector has revealed that the dominant research paradigm in this field of knowledge is interpretivist. Indeed, there are two main reasons from which we can infer this behaviour in academia.

Firstly, there is the fact that industry has specific knowledge yet undiscovered by researchers and therefore, is ahead from academia in the understanding and use of particular environmental technologies. Some theoretical assumptions have been proved wrong in practice and new environmental management practices are constantly being tested within the sector, i.e. alternative fuels, disassembly manufacturing plants, and so on.

Secondly, the existing structure of the automotive sector (large manufacturing plants, joint-ventures, and global outsourcing) creates a large barrier for the entrance of new players. This fact leads to implications on the access to major companies, making the investigation of their managerial data related to environmental issues a difficult and complex task. For this reason, the benefits of case research are clear as it allows the development of a closer relationship between a company and a researcher, allowing in-depth understanding of contemporary events.

However, engineering and natural sciences schools have also developed considerable studies in this field, and their approach is usually positivist and associated with quantitative methods. Also in this approach, green supply chain studies can be found in order to quantify the relevance of environmental practices among car assemblers' suppliers.

In summary, those who test materials to make cars more environmental-friendly products are usually using positivist approaches. These studies focus primarily on *what* to do to become greener. On the other hand, other researchers that analyse the development of environmentally sound processes, changes in the production system and implementation of new methods tend to use non-positivist approaches in order to explain *why* and *how* companies are going to achieve a higher environmental performance.

Having said that non-positivist approaches are dominant in the research regarding the sustainability of the automobile industry; evidence of this dominance is provided through the analysis of 17 papers in a special issue on this topic of the Journal of Cleaner Production and 2 more peer-reviewed journal papers.

3.3 The positivist school of thought in sustainability management

Positivist studies on sustainability of the automobile industry basically deal with issues related to fuels, materials, costs, waste measures, and also, logistics and supply chain management. These studies are based on a philosophical underpinning that there is an objective reality behind the facts and the results can be generalised. Indeed, some characteristics of fuels, materials, and even cost-based transportation models are often passive of generalisation. Most of these pieces of research try to explain the facts using statistical tests to argue their conclusions. In these studies, empirical methods are used to represent performance and are very useful in making numerical comparisons.

For example, Cousins, Bueno and Coronado, (2007) show the failure of the policies to minimise atmospheric pollution. They use quantitative models to show that there is an inverse fuel efficiency relationship with weight and with vehicle power. In addition, the authors found that power was extremely expensive in the early part of the century; nevertheless, nowadays power has become much cheaper and available in much greater absolute amounts. Their claims can be generalised and sustained over long period of time.

Another example of a positivist approach is given in the application of financial and life cycle models by Duval and MacLean (2007). They looked at the incremental costs for removing plastic in end-of-life vehicles through a case study approach in a dismantling, warehousing and distribution company. Two models were used; one for the financial analysis and the other to estimate and compare the greenhouse gas emissions and energy requirements of current and proposed operations for a plastics recycling network. In the end, there is little room for subjective analysis and although the results may not be generalised for worldwide operations due to the different cost in different countries, the model itself may be generalised after being tested in different contexts.

Moreover, other studies regarding waste, fuel change and type of material are using positivist approaches. Giannouli, Haan, Keller and Samaras (2007) present a model to predict the waste produced from road vehicles, both at their end-of-life and during the vehicle operation. Spielmann and Althaus (2007) also took a life-cycle approach model to evaluate if prolonged use of a passenger car reduces environmental burdens in Switzerland. Haan, Peters and Scholz (2007) investigate the energy consumption reduction in road transport through hybrid vehicles. Tharumarajah and Koltun (2007) report a life-cycle environmental assessment of engine blocks in order to find environmental benefits of using magnesium rather than aluminium, because the first is a lighter metal. Zah, Hischier, Leao and Braun (2007) evaluate the prospective environmental impacts of automobile applications of curaua fiber.

Zhu, Sarkis and Lai (2007) developed a questionnaire and targeted managers at middle or higher management levels to investigate general green supply chain management practices, pressures/drivers, initiatives and performance of the automotive supply chain in China. The final aim is to generalise the results for automotive sector in developing countries.

Although the positivist school of thought is very valuable for areas of sustainability management (e.g. materials and environmental sciences); there are limitations with regard of their capacity for theory building and provision of in-depth understanding of business sustainability aspects, mainly in the early stages, when the concepts and relationship between variables are not yet mature.

3.4 The Interpretivist school of thought in sustainability management

Several researchers from different disciplines (e.g. business, engineering, economics, geography, etc) adopted interpretivist approaches to first understand the recent changes in this industry and evaluate the actions taken by the companies in the automotive sector. The development of theories from an interpretivist view is also possible on issues such as radical changes on production networks, fuel change, culture of automobile, new business models and public policies. The implementation of environmental management systems were also treated by interpretivist approaches due to the very different contexts and needs from one company to another. The contributions of this school of thought are strongly related to theory building, but not necessarily with the aims of generalisation of research results.

Gernuks, Buchgeister and Schebek (2007) described the elements of the comprehensive systematic approach applied in Volkswagen’s production sites. Their research methodology involves a quantitative assessment of environmental impacts; however, the results cannot be generalised because of the uncertainties of the method, which was adequate for Volkswagen's German production sites and may not be applicable generally at a global level. The method itself may not to be applied in different industries, countries or companies as it was developed on single case study research strategy. The aim of Gernuks et al (2007) study was to develop procedures for Volkswagen. Also in Volkswagen, Koplin, Seuring and Mesterharm (2007), present one approach to integrate social and environmental standards into supply chain management. These authors affirm: "To prove the universal validity of the concept (sustainable supply chain management), other action research projects must be initiated, and/or multiple case studies must be carried out".

Interestingly, the problem of product recovery, which was dealt with through a positivist approach by Giannouli et al (2007), is analysed by Seitz (2007) and Smink (2007) using a qualitative and non-positivist paradigm. Seitz (2007) has taken a multiple case study approach using structured and semi-structured interviews, including interviewees from all functional levels. Smink (2007) uses Denmark as an example to analyse the extent to which environmental regulations have driven changes in the Danish car-dismantling industry. Both Seitz (2007) and Smink (2007) make explicit their intentions of examining further the motivation for product recovery.

The papers reviewed in this section have basically the same objective of understanding *what, why and how* the automobile industry is doing in order to meet environmental demands from public regulation agencies and from society. They are examples of how the choice of non-positivist approaches and the predominant use of qualitative methods are related to the nature of their studies, which focus on gaining deeper knowledge to help advance theory and practice on how to enhance the sustainability of the sector.

3.5 Comparing qualitative and quantitative research designs

Although there is a predominance of non-positivist approaches and qualitative methods, the use of positivism and quantitative analysis are very important to answer the research question: "How do we achieve a sustainable automobile industry from the green operations perspective?"

The green operations perspective is based upon the introduction of environmental criteria in all operations decisions. It embraces five environmental practices: green buildings, eco-design, green supply chains, green manufacturing, and reverse logistics. Thus, depending on the scope of analysis and the objective of the research the use of quantitative, qualitative or even, the combination of both will be valid.

In short, on studies concerning sustainability of the automobile industry, a predominance of non-positivist approaches and an intense use of qualitative methods were found. However, when the practices and knowledge are established in the industry and academia, researchers tend to start using quantitative methods through positivist approaches. They attempt to prove the significance of materials and practices to the companies' environmental performance. Positivist and non-positivist approaches were also combined in some publications to achieve a better understanding and explanation of the relationship between the industry and the use of environmental technologies.

Once breakthroughs are suggested in qualitative studies, researchers start using mathematical models to forecast costs, time and therefore, the impact of the solution in the sector. Regulation for end-of-life vehicle, emissions control and material composition of the cars are examples of the use of a positivist approach following non-positivist studies. Although the non-positivist approach is currently dominating this field of research, both philosophical paradigms and methods (qualitative and quantitative) are important to the development of expertise on the topic of sustainability of the automobile industry.

3.6 The organisational management research designs

There are many factors that affect research designs. Primarily, the philosophical position, as discussed above, has the major impact (Easterby-Smith et al, 2008). The main reason to choose a particular research design is the support given the research ontology and epistemology, i.e, the values and worldview that will ultimately underpin the construction of knowledge. Within the research design, a research methodology and its methods will be chosen.

A number of research designs are said to have more potential links to positivist epistemology, namely: experimental, quasi-experimental, and surveys. Non-positivist approaches favour research designs such as case method, action research, ethnography, grounded theory, narrative methods, etc.

Within these research designs, it is possible to select and apply quantitative and qualitative methods. Usually, positivist research designs are associated with quantitative methods; nevertheless, it is possible to use qualitative data in a positivist research design.

From the history of natural sciences, many important discoveries came from experiments and qualitative analysis. Take as an example Galileo and Newton's research:

> "Galileo conducted a series of experiments to explore the variables that cause an object to stay on top of water or move (sink, rise). In many of these experiments, no quantitative measurements were taken, and the report of the experiments rarely includes numbers. Isaac Newton's experiments with prisms and light diffraction were also primarily qualitative in nature. Their essence was to examine how the colour of light changed under different interventions." (Shadish, 1995).

In fact, qualitative and quantitative methods can be combined in the same research design. For instance, qualitative data can be used as input to identify constructs that will compose a survey where data will be quantified and statistically analysed. Data triangulation is also common in scientific research in order to enhance rigour and the validity of research designs.

A research design must concern the project's research questions, which of course should be based upon and represent the philosophical position of the investigation. Thereby, research questions become important evidence to the appropriate choice of methodology and research methods. For instance, Yin (2003) explains that case research is appropriate for 'why' and 'how' research questions, but not necessarily appropriate to questions of 'whom', 'what', and 'where'. According to Yin (2003), case research provides advantages over other research methods for investigations where contemporary events need to be included and control of behavioural events is difficult.

3.7 The choice of research methodology: The reasons for qualitative case research

Today, there still is an enormous debate on the concept of sustainability, how to measure environmental performance, why and how companies should go green, amongst other issues. Moreover, the automotive industry, the particular interest of this research study, is immersed in a cauldron of ambiguity. The literature and practice of sustainable or green operations in the automotive industry is not clear on how companies take environmental decisions (e.g. based on environmental impacts, product-based or process-oriented improvements?). In practice, there is little evidence on the strategic role of environmental decisions. The level of uncertainty and complexity are high for those decisions, and the way to measure success is also not clear.

These facts led to the assumption that the ontology field is rather more subjective than objective, and it is necessary to understand the environmental decisions within their context before trying to judge them as good or bad. The research questions of this study are intended to shed light on the drivers, origins of ideas, and the decision making processes in a way that will enable generalisation of broad rules of sustainable decision making in manufacturing organizations.

As evidence from the philosophical perspective taken in this field so far, a literature review on the topic of sustainability of the automotive sector has revealed that the dominant research paradigm in this field of knowledge is interpretivist. To give evidence of this dominance, the special issue on “The Automotive Industry & Sustainability” in the *Journal of Cleaner Production* (Volume 15, Issues 11-12, 2007), published several papers using methods such as case study and action research. Other papers in the literature review show the importance of considering different contexts of companies and countries to embrace sustainability.

Having different market segments, environmental regulations and environmental performance measures justifies the use of qualitative analysis to understand and explain how companies deal with different environmental pressures and adopt sustainable practices. Being in the early stages of Green Operations studies, the aim of this investigation is to assist in the construction of a body of knowledge that can help companies to undertake better environmental decisions considering its own context.

In support of this choice, there is also the experience of other scholars who have tried to connect the environmental pressures and drivers to the adoption of green operations practices, and examine the relationship of these practices to performance. Zhu et al (2005) explain that a positivist and quantitative methodology of survey questionnaires were not able to confirm the connection between drivers, practices, and performance as expected. Zhu et al (2007) had to supplement their survey questionnaire study with a case study approach in order to gain in-depth insights about these connections:

> "To provide depth and enhancement (e.g. initial evaluation of causal relationships among factors) to our empirical findings, we provide a detailed analysis on one Chinese automobile engine manufacturer, the Dalian Diesel Engine Plant (DDEP), evaluating some of their GSCM practices. This company has initiated Green Supply Chain Management practices that exemplify various performance improvements" (Zhu et al, 2007).

Voss, Tsikriktsis and Frohlich (2002) explain the importance of case research in operations management. Besides highlighting the need for rigour in conducting the research, they also discuss the use of complementary methods to increase reliability and the importance of being flexible and open to accept feedback from the system (research context) to find valuable insights and build powerful theories. Furthermore, the feedback from the interviews might cause the research questions to evolve during a case research:

> "When conducting a case-based research, it is not uncommon for the research question to evolve over time and for the construct to be modified, developed or abandoned during the course of the research. This can be a strength, as it can allow the development of more knowledge than if there were just a fixed research question. Again, over time the research may shift from theory building to theory testing. This should be recognised on the one hand, but not used as an excuse for inadequate specification of research questions or constructs" (Voss, Tsikriktsis and Frohlich, 2002).

In short, the choice of qualitative methodology is justified by its power when dealing with the chosen research questions in a field that has not reached its maturity yet regarding concepts, measures, constructs, as well as wider theories for sustainable operations.

Thus, the alignment of the methodology choice with the philosophical aspects of this investigation on green operations and environmental decision making is presented in Table 3.1. The ontological view taken in this investigation is that reality is subjective, since sustainable operations management theory and practice are in early stages of development. Thus, this leads to an epistemic view that knowledge is being created. The study then should consider any contextual influence by which only decision making patterns can be generalised rather than the decisions themselves. In addition to the ontological and epistemic analyses, the axiology of this investigation is primarily aimed at increasing the understanding of environmental decision making processes within operations function of manufacturing organisations. Finally, the reasons to use the qualitative methodology are given due to the contextual complexity and dynamics associated with contemporaneous research questions.

Table 3.1 – Philosophical aspects of this research based on nature of the research problems and methodology literature

Philosophical aspects and the research choices
Ontology: reality is subjective for the environmental sustainability of companies. There are different worldviews in different parts of the world for the same concepts and facts. Although the issues related to emissions, environmental impacts and aspects can be understood in a quantitative and objective world, the environmental decisions are within a subjective dimension which varies according its context.
Epistemology: knowledge is currently being created on both theory and practice of green operations. As a consequence of its early stages, the nature of the knowledge is particularly linked to its time and place, which creates strong limitations to generalisability of environmental decisions; however favouring the investigation on the patterns of environmental decision making processes in an interpretivist approach
Axiology: the value of this research is mostly on its contributions to increase understanding of environmental decision making. In coherence to its ontological and epistemic views, the explanation and prediction of the field are limited since it is necessary a deeper understandings of the events on this field of knowledge.
Methodology: considering that a study on green operations and environmental decision making is a dynamic and contemporary event embedded in a contextual complexity of organisations, the methodology is qualitative.

3.8 Research Questions

The fundamental question that motivates this study is “Why and how are automobile manufacturers taking environmental decisions for the operations function?”. After a comprehensive literature review, this investigation was developed into four research questions identified as being relevant to the subject of research and more primarily motivated within the context of the automotive industry, and eventually, extended to other sectors:

- RQ1: In what way does the context play a role in the environmental decisions of companies?
- RQ2: What are the drivers for manufacturing companies to take environmental decisions?
- RQ3: Where do (environmental) solutions come from?
- RQ4: Does a structured approach contribute to effectively improve environmental decisions?

The following sections discuss the methods to investigate the research questions and their respective justifications.

3.8.1 RQ1: In what way does the context play a role in the environmental decisions of companies?

The investigation of this research question was carried out through a qualitative analysis of green operations initiatives. The data was collected through environmental and sustainability reports of the largest automotive corporations in USA, Europe, and Japan. Data was analysed through content analysis.

The criteria of analysis and benchmarking were established by a green operations categorisation developed by the author, which was based on and adapted from the literature as shown in Table 2.1 in the Literature Review Chapter and used to develop the Green Operations Framework (see Chapter 8).

3.8.2 RQ2: What are the drivers for manufacturing companies to take environmental decisions?

Previous studies have indeed investigated the main drivers and pressures for environmental decisions. Sarkis (2010) notes that there have been changes since that time but there are other aspects that remain the same:

> "For example, the pressures from a variety of stakeholders including regulators, communities, shareholders, customers, employees, non-governmental organizations, and competitors on various natural environmental issues, still exist. The difference is that many aspects of these pressures have become even more pronounced. Part of these changes and increased awareness arose from economic and geopolitical forces that have caused organizations to further consider the importance of greening their industries" (Sarkis, 2010)

The reasons for investigating drivers, although there has already been a continuous and reliable body of knowledge in the field, is the fact that a gap still exists when it comes to understanding the different influences and roles each driver may play on decisions. And as previously mentioned, little is known about the relationship between pressures/drivers and adoption of environmental practices and consequential improvements in performance (Zhu et al 2007; Zhu et al, 2005)

Data were collected through interviews and focus group discussions with individuals or teams who were involved in environmental decision making. The case study research strategy enabled a deeper understanding through a collection of relevant details about the relationships between drivers and different green operations practices. Participants belonged to different department, namely: environmental department, production, supply chain, and product development.

The techniques used for data analysis are discussed in section 3.12 of this Chapter.

3.8.3 RQ3: Where do (environmental) ideas come from?

There is limited literature and awareness about the origins of ideas for environmental initiatives. With the increasing importance of outsourcing, many solutions which may be seen implemented in various organizations may have been created outside the company. It is vital to have a better understanding of whether companies are developing internal capabilities to undertake environmental decisions or if they are relying upon external experts and transferring this responsibility. In order to investigate this question, this research project used qualitative methods such as personal interviews and focus groups with environmental decision makers and teams.

3.8.4 RQ4: How does a structured approach contribute to effectively improve environmental decisions?

This research question relates to the *GRASS* (Greener Approach to Systems Strategy) model - a systems model developed by the author. Due to the lack of a structured approach for environmental decisions found in the interviews, this thesis offers a process for environmental decision making. The model was populated, evaluated, critically analysed in a real decision making situation in order to answer the above research question.

The method used was focus group. Through a focus group it was possible to test and evaluate the model in a real decision making situation. There were two sessions with a higher-education institution which is developing its environmental strategy.

More detailed explanation about the use of service-operations firm is provided in section 3.9.3.

3.9 Research Methodology

The research had three distinct phases, as described in Figure 3.1: (i) Initiation – Green operations Classification and Conceptual Framework, (ii) Case Research and (iii) Systems model development, testing, and evaluation. The chronology of the research project activities is shown in Figure 3.2.

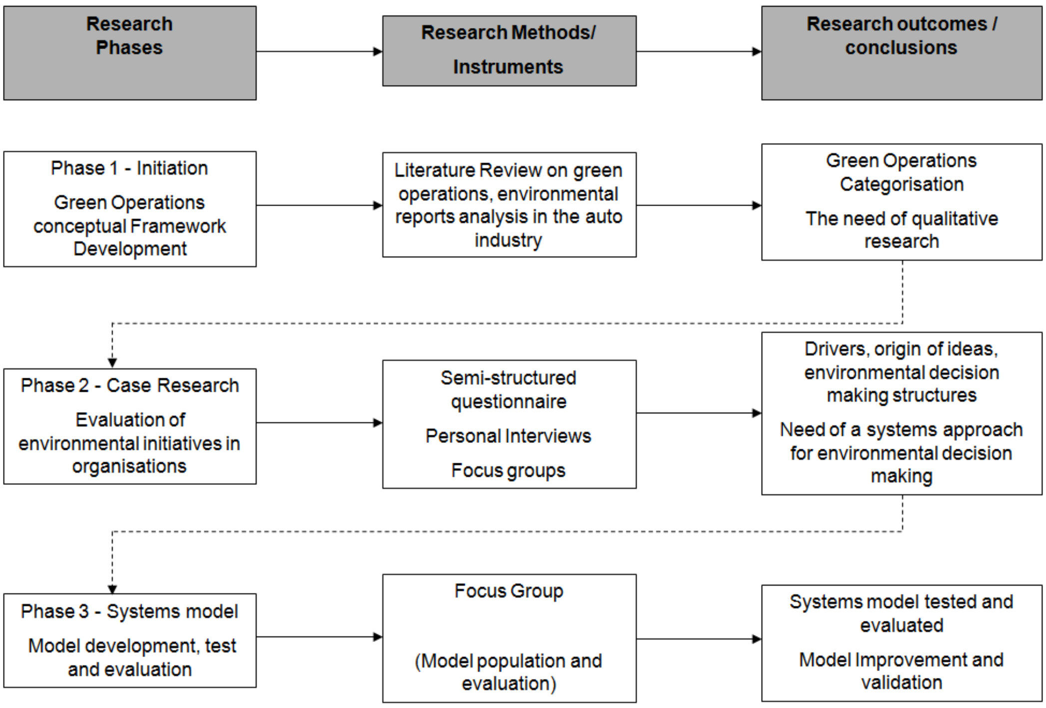

Figure 3.1. Research phases, methods and outcome conclusions of each phase

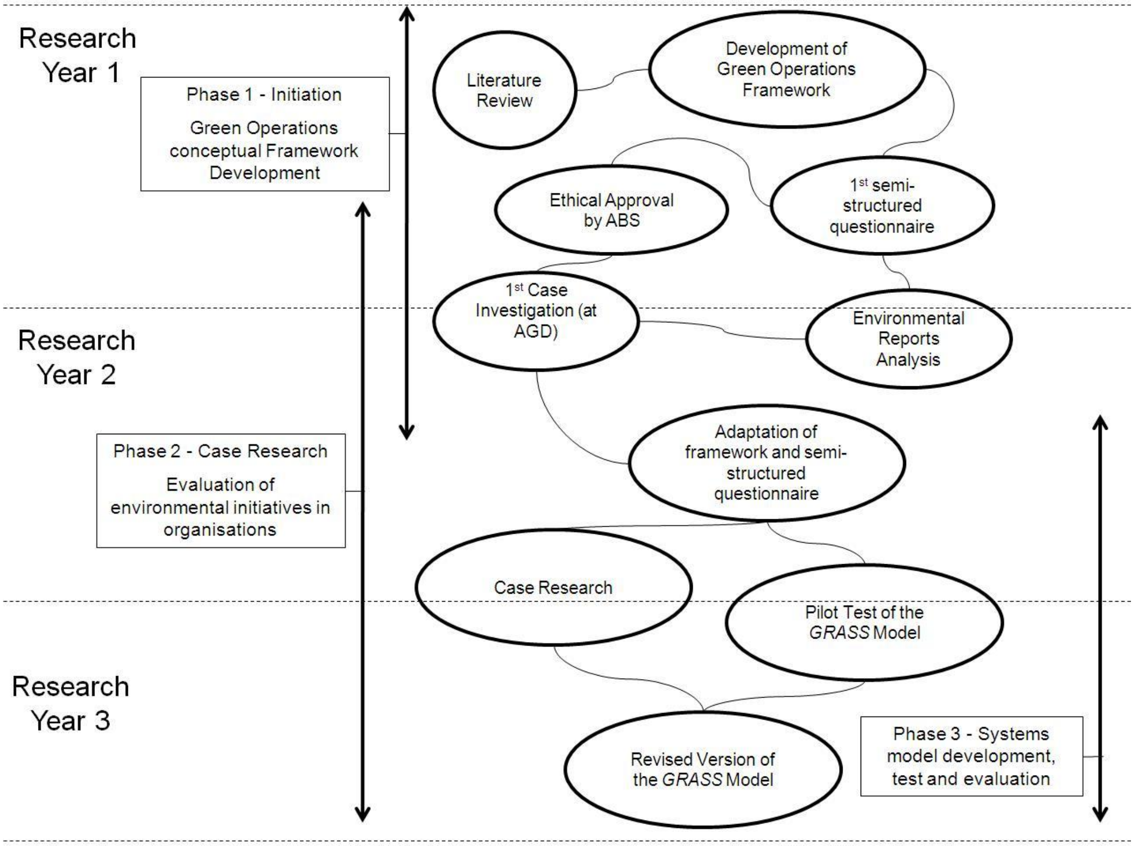

Figure 3.2 – Chronology of the research project activities

As Figure 3.2 shows, the research project took three years to complete the investigation phases. The data analysis and writing of this PhD thesis took place in year 4, which is not represented in Figure 3.2. Also, it is important to note that the necessary Ethical approval was obtained from the Aston Business School Research Ethics Committee. The access to the first case (AGD) was given through contact from Aston Alumni office in the first year of the research project. Despite the taking place in the first year, the interviews in first case were already in accordance to the Aston Business School Research Ethics procedures. All interviewees were given a research consent letter (see appendix 6).

3.9.1 Phase 1: Initiation - green operations conceptual framework development

The literature review undertaken to develop the green operations classification included academic and industrial publications. Figures 2.2 and 2.3 and table 2.1 show the classification that served as the basis to develop the Green Operations Framework (see Chapter 8). Environmental reports of automotive companies (General Motors, Volkswagen, Toyota) were used to compare company practices with the latest theory. Five main practices emerged from these literatures: green buildings, eco-design, green supply chains, green manufacturing, and reverse logistics, but also prevalent was the importance of innovation to achieve higher levels of sustainability and improved environmental performance. From a decision making perspective, this phase shows the levels of strategic decisions, which are presented in Figure 2.3.

Table 3.2 – Environmental reports analysis: Companies, Brand Nationality, Industrial Sector, Area of research, Research Method, Main source of data and decision level in each company

Companies (Brand nationality)	**Industrial sector (Plant location)**	**Area of research**	**Research method**	**Main source of data and decision level**
General Motors (USA)	Auto (Worldwide)	Operations Function	Secondary data analysis	Environmental Report (All corporate levels in operations)
Volkswagen Group (German)				
Toyota Motor Corporation (Japan)				

3.9.2 Phase 2: Case research

The research instruments used in this phase were mainly personal interviews and focus group, although environmental reports and internal documents were also analysed. Interviewees were contacted by phone or e-mail primarily and received a research cover letter in order to be informed about the research objectives prior to the interview (see appendix 1). Also in the end of the thesis, appendix 2 shows how the activies were planned in the research design.

The scope and choice of cases were driven by the activities shown in Figure 2.3. As mentioned earlier in Chapter 2, environmental decisions can take place at various levels: corporate strategy, operations strategy, product and process development and improvement, amongst other areas of operations (facilities, supplier relationship, logistics, etc). Tables 3.3 and 3.4 present the companies that were part of the case research phase linking the cases to their specific area of research within the operations function. Table 3.3 shows the automotive companies in this investigation and the different countries, areas of operations, number of participants, as well as the time spent in interviews and focus groups in each case. Note that “Birmingham Premium Cars” is duplicated in the table because there were two cases within the same company. That happens because the decision making team is the unit of analysis in this investigation. Therefore, due to the fragmentation between decisions in manufacturing and product development the interviewees were part of two different decision making teams; hence, two different cases are presented.

Table 3.4 shows the non-automotive companies included in this research investigation. There are five industrial sectors and two main data collection methods applied: personal interviews and focus group (See appendix 3 for the semi-structure questionnaires used in the interviews). In fact, in one of the cases (University), three methods were used (interviews, focus group, and survey) aiming at populating, testing and evaluating the *GRASS* model.

Table 3.3 –Automotive Companies, Brand Nationality, Industrial Sector, Area of research, Research Method, Number of participants, duration of data collection in each case

Companies (Brand nationality)	Industrial sector (Plant location)	Area of research	Research methods	Number of participants (job position)	Hours of data collection (total)
Auto Group of Deutschland (German)	Car Manufacturer (USA)	Operations function	Interviews & Environmental reports	3 managers (environmental, communications and energy)	4 hours
German Premium Cars (German)	Car manufacturer (Germany)	Product development	Focus group	6 (Engineers / Product development team)	3hours
Waltham Luxury Cars (British)	Car manufacturer (UK)	Manufacturing	Personal interviews & Environmental reports	1 (Environmental Manager)	3 hours
Birmingham Luxury Cars (British)	Car manufacturer (UK)	Manufacturing	Personal interviews	1 (Environmental management team member)	2 hours
Birmingham Luxury Cars (British)	Car manufacturer (UK)	Product Development	Personal interviews & Environmental reports	1 (Sustainable mobility team member)	2 hours
Japan Motor Corporation (Japanese)	Car manufacturer (Thailand)	Manufacturing / Supply chain	Personal interviews & Environmental reports	2 Environmental Manager and Assistant	4 hours
Parts distributions (French & British)	Automotive (UK)	Warehousing and reverse logistics	Personal interviews	1 Warehouse manager; 1 waste manager	4 hours

Table 3.4 – Non-automotive Companies, Brand Nationality, Industrial Sector, Area of research, Research Method, Number of participants, duration of data collection in each case

Cases (Brand nationality)	**Industrial sector (Plant location)**	**Area of research**	**Research methods**	**Number of participants (job position)**	**Hours of data collection (total)**
Thailand King's Sea food (Thai)	Food processing (Thailand)	Manufacturing / Supply chain	Personal interviews	1 Managing Director's Assistant	2 hours
Thai Garments (Thai)	Garment manufacturing (Thailand)	Manufacturing / Supply chain	Personal interviews	1 CEO	2hours
Chemical Company of Thailand (Thai)	Chemical processing (Thailand)	Manufacturing / Supply chain	Personal interviews	2 Top administrators	4 hours
UK Premium Carpets (British)	Carpet producer (UK)	Manufacturing / Supply chain	Personal interviews	1 Environmental manager	1 hour
University (British)	Higher Education (UK)	Social Responsibility and Sustainability coordinators	Interviews, Focus Group, and survey	2 programme coordinators	6 hours

3.9.3 Phase 3: Systems model development, test, and evaluation

The theoretical underpinning used for the development of the *GRASS* model resides in the disciplines of environmental management, systems thinking, and strategic operations management. To populate, test, and evaluate the model, it was applied to help with designing the green research strategy of a university. The coordinators of Social Responsibility and Sustainability programme were interviewed individually and participated in two 2-hour workshops where they used and evaluated the model, including completing a final survey. Platts (1993) and Platts, Mills, Bourne, Neely, Richards, and Gregory (1998) recommends testing feasibility, utility and usability of models. Following Platts's recommendations, a focus group presented as the best alternative to populate, test, and evaluate the *GRASS* model. Appendix 4, in the end of the thesis, shows the focus group protocol for *GRASS* Model application.

Platts (1993) provides definition to the concepts of feasibility, utility, and usability. According to the author, feasibility is understood as the ability of the model to be implemented in its whole. Utility refers to its capacity in delivering what it was designed to do, while, usability is measured by the easiness of future utilisation without a model expert facilitation.

The focus group included a questionnaire survey (see appendix 5) to capture participants' opinions on feasibility, utility, and usability. It was found that feasibility and utility of the model were better rated than its usability. Thus the model was able to be followed and to solve problems; however, assistance may be required to ensure its appropriate use and the consequent benefits from its utilisation.

Both focus groups were recorded and analysed to improve the model (for techniques of data analysis, see section 3.12). The main benefits for participants related to enhanced consistency of decision making and how the model structured their thoughts, although this was at the expense of the time consumed.

The *GRASS* model is presented in chapter 8 and intends to contribute to the green operations literature and practice, mainly with respect to environmental decision making. Systems thinking methodology was used to turn the green operations framework (Nunes and Bennett, 2008) into a systemic tool as mentioned before. The model application supplements a wider research project that aims at understanding why and how automotive companies are taking environmental decisions. The model itself helps to answer the research question four: “how does an environmental decision making model (a structure approach) contributes to making strategic environmental decisions for operations function in the automotive industry?”

It is important to say that the *GRASS* graphic is selective and illustrative in order to represent the recommended flow of activities and their stronger links. During its application it is possible to achieve deeper levels of detail and understanding of the environmental decision making processes.

Due to the level of detail explored with the model, case research is used and the main research method is focus group for data collection and the model population, testing, and evaluation.

This phase of the investigation had one case with one unit of analysis. It was considered that a decision making team as the unit of analysis and followed the logic for generalising the results supported by Yin (2003): “Case studies are generalizable to theoretical proposition and not to populations or universes”. In this sense, from the model application, we want to generalise the contribution of our decision making structure and the potential benefits of systems thinking to green operations strategy.

Decision making teams would configure as a valid measure once they will be composed of different people or formed for a different purpose and going through a real decision making process. Finally, Mintzberg (1979) points out: “No matter how small our sample, or what our interest, we have always tried to go into organisations with a well defined focus”

Figure 3.2 had shown the chronology of the research, which illustrate well the chain of events that were followed in order to build the theories on how companies take environmental decisions, the process of decision making, and the suggested approach represented by the *GRASS* model.

3.10 Selection and Presentation of cases

The unit of analysis in this study is the environmental decision making team or the environmental decision maker him/herself. Thus, the selection of cases in this research investigation was made based upon the value of each case to the main contribution of this thesis: “Why and how are companies taking environmental decisions for operations function?”. Table 3.5 shows the characteristics of each case and the use of research methods, and Table 3.6 presents how each case is related to the main contributions of the thesis: green operations framework, environmental decision making, and the systems thinking model. Table 3.7 clarifies the philosophical approach, and the involvement and role of the researcher in each case.

Table 3.5 – Cases and the use of interviews, focus group, environmental report analysis, single factory analysis and production volume

Cases (Brand nationality)	**Interview / focus group (FG)**	**Environmental Report analysis**	**Single factory analysis**	**Production volume**
General Motors (USA)	No	Yes	No	High
Volkswagen Group (German)	No	Yes	No	High
Toyota Motor Corporation (Japan)	No	Yes	No	High
Auto Group of Deutschland (Germany)	Yes	Yes	Yes	High
German Premium Cars (Germany)	Yes (FG)	Yes	Yes	High
Waltham Luxury Cars (UK)	Yes	Yes	Yes	Low
Birmingham Premium Cars, Sustainable Mobility (UK)	Yes	Yes	Yes	Low
Birmingham Premium Cars, AME (UK)	Yes	Yes	Yes	Low
Japan Motor Corporation (Japanese)	Yes	Yes	Yes	High
Parts distributions (France & UK)	Yes	No	Yes	High
Thailand King's Sea food (Thailand)	Yes	No	Yes	High
Thai Garments (Thailand)	Yes	No	Yes	High
Chemical Company of Thailand (Thailand)	Yes	Yes	Yes	High
UK Premium Carpets (UK)	Yes	No	Yes	High
University (UK)	Yes (FG)	Yes	Yes	High

Table 3.6 – Cases and their link to the thesis's contributions

Cases (Brand nationality)	Green Operations Framework	Why and How to companies green	Nature and structure of decision making	Systems Thinking decision making model
General Motors (USA)	High	Medium	Medium	Low
Volkswagen Group (German)	High	Medium	Medium	Low
Toyota Motor Corporation (Japan)	High	Medium	Medium	Low
Auto Group of Deutschland (Germany)	Medium	High	Medium	Low
German Premium Cars (Germany)	Low	High	High	High
Waltham Luxury Cars (UK)	Low	High	High	Medium
Birmingham Premium Cars – Sustainable Mobility, (UK)	Low	High	High	Medium
Birmingham Premium Cars - AME (UK)	Low	High	High	Low
Japan Motor Corporation (Japan)	Medium	High	High	High
Parts distributions (France & UK)	Low	High	High	Medium
Thailand King's Sea food (Thailand)	Medium	High	High	High
Thai Garments (Thailand)	Low	High	High	Low
Chemical Company of Thailand (Thailand)	Medium	High	High	Medium
UK Premium Carpets (UK)	Medium	High	High	High
University (UK)	Yes	Yes	Not	Yes

Table 3.7 – Cases, approach of research method and the involvement and role of the researcher

Cases (Brand nationality)	**Involvement of the researcher**	**Role of researcher in data collection**
General Motors (USA)	Detached	Download publicly available Environmental Reports
Volkswagen Group (German)	Detached	Download publicly available Environmental Reports
Toyota Motor Corporation (Japan)	Detached	Download publicly available Environmental Reports
Auto Group of Deutschland (Germany)	Semi-Detached	Conduct semi-structure Interviews, observation, and analyse environmental report
German Premium Cars (Germany)	Semi-Detached	Conduct semi-structure focus group activity
Waltham Luxury Cars (UK)	Semi-Detached	Conduct semi-structure Interviews, observation, and analyse environmental report
Birmingham Premium Cars – Sustainable Mobility, (UK)	Semi-Detached	Conduct semi-structure Interviews, and analyse environmental report
Birmingham Premium Cars - AME (UK)	Semi-Detached	Conduct semi-structure Interviews
Japan Motor Corporation (Japan)	Semi-Detached	Conduct semi-structure Interviews and analyse internal reports
Parts distributions (France & UK)	Semi-Detached	Conduct semi-structure Interviews, and observation
Thailand King's Sea food (Thailand)	Semi-Detached	Conduct semi-structure Interviews, and observation
Thai Garments (Thailand)	Semi-Detached	Conduct semi-structure Interviews
Chemical Company of Thailand (Thailand)	Semi-Detached	Conduct semi-structure Interviews, and observation
UK Premium Carpets (UK)	Semi-Detached	Conduct semi-structure Interviews
University (UK)	Involved	Facilitate an environmental decision making workshop

3.11 Ensuring research rigour

The literature on case study research raises the concerns of bringing rigour necessary to make qualitative methodologies relevant and acceptable by the wider academic community (Gibbert and Ruigrok, 2010; Scandura and Williams, 2000).

Suggestions to make case study research rigorous are found in several qualitative books (Yin, 2003; Bryman, 2008; Eisenhardt, 1989; Miles and Huberman, 1984). Most of the scholars recommend that qualitative researchers explain how their investigation builds the validity of constructs, internal and external validity, as well as reliability. Below, it is explained how these issues were addressed in this thesis.

Construct validity

Construct validity was addressed in this investigation in the early stages of its research design. First, the green operations practices were identified in the literature and adapted in order to have a more consistent categorisation as well as bridge with reality. The environmental reports were important in constructing this connection between academic and industrial language. Then, the drivers for environmental decisions were mapped from previous studies where the relationship between drivers/pressures, green operations practice implementation and environmental performance was also stated. In addition, the first case study (Auto Group of Deutschland) carried out in this research project had the intention of testing the feasibility of the original research design based upon a longitudinal case study using the green operations classification (Figures 2.2 and 2.3).

A semi-structured questionnaire proved very instrumental to guide the investigation towards its main objectives, ensuring that the research had improved construct validity.

Internal validity

Internal validity refers to the presence of causal relationships between the variables and results. It was addressed in this study through three main routes: (1) the use of semi-structured questionnaires; (2) data triangulation; and (3) robust data analysis procedures.

Besides helping in enhancing construct validity, the semi-structured questionnaires allowed the research to link drivers to environmental decisions and initiatives, the context where the company was operating, and the process of decision making. By permitting the construction of these causal relationships in a structured approach, the questionnaires contributed significantly towards internal validity. The time dimension was included as well as the level of difficulty on taking an environmental decision or measuring the success of a decision. The construct of tangibility emerged from the interviews and could be later linked and confirmed when revisiting the environmental reports of GM, Toyota, and Volkswagen.

When possible, internal and external environmental reports, and news from the media were used to check the accuracy of information from the interviews particularly for dates, performance measures, and other factual data.

Most important for internal validity were the data collection and analysis procedures used in this thesis. It was possible to record most of the interviews which allowed the researcher to re-visit the data at anytime during the data analysis phase. When recording was not possible, due to company’s internal rules or noise from the factory environment, the notes of the interviews were taken, typed and sent back to the interviewee for feedback and accuracy check. The research design for this investigation gave significant value to the richness found in the breadth of a multiple case study approach which led to a short but sufficient time with each case company. Thus, due to the duration of each interview, the nature of the data collected, and lastly, the structured approached used in the investigation, the use of transcription and coding was not necessary. The reports produced for each unit of analysis, including those recorded, were e-mailed back to interviewees for their appreciation and consent for publishing. These reports are presented in chapter 5 and 6. Although primarily descriptive, they were explicit on the emergence of the causal relationship between the constructs and the answers for the research questions that this investigation has aimed to answer.

External validity

The issues of external validity are those related to the generalisability of findings and results of any given research (Gibbert and Ruigrok, 2010; Lee, 2003, Numagami, 1998). This research project has tackled the external validity of the study on three main criteria: geographical location, industrial sector, and organisational culture.

Environmental reports were selected based upon the location and size of the automotive companies (USA, Europe, and Japan), and primary data were collected in companies operating in four different countries: the UK, Germany, Thailand, and the USA. Considering this factor, this research tried to overcome possible bias of sampling organisations that operate under a single environmental legislation or in only developed-country contexts.

The extension of the research beyond the automotive sector endeavoured to enhance the generalisation of findings and results towards other manufacturing sectors. Nevertheless, all companies participating in the research were involved in global trade, therefore the results here may not necessarily be applicable to some domestic companies.

The diversity of the cases in terms of geographical location and industrial sector minimised the impact of another significant possible factor – the organisational culture. By investigating companies in different countries and industrial sectors as well as different brand nationalities, the influence of organisational culture was reduced.

Reliability

For each case in this research project, there was a case protocol. As mentioned before, the interviews were audio recorded in most cases and when not possible, procedures were taken to improve data accuracy and analysis. Reliability issues were addressed during the data collection phase by selecting evidence-based environmental initiatives which carried objective reality. For instance, the environmental initiative analysed at the AGD-USA case was a landfill gas project where the facilities could be visited. The concept of sustainable factory at the JMC case was discussed and the environmental reports and internal documents could be checked. Another example is the construction of a biomass plant at TCC. By using concrete and implemented projects as evidence of environmental initiatives alongside the audio recording and notes from the interviews, the data analyses were able to have high level of replication.

As a result, this research investigation became robust because data collected is reliable using valid constructs represented in semi-structured questionnaires. Besides, the scope for errors and flaws in the data collection methods and analysis were minimised by using the procedures explained here. Section 3.12 will elucidate the techniques used for data analysis.

3.12 Techniques of Data Analysis

After data were collected through the methods presented in Tables 3.3 and 3.4, qualitative data analysis techniques were used to structure the path from data to findings to results.

For the environmental reports analysis, the whole environmental reports of each company were printed, and notes were taken about the environmental initiatives. Initiatives were then classified according to the Green Operations Classification (also shown in Figures 2.2 and 2.3) in a content analysis technique. This categorisation helped to differentiate process-based from product-oriented environmental initiatives and linked the environmental practices to their respective activity in the operations function. By doing this, the benchmarking of green operations practices became more reliable, as well as broader since environmental initiatives in facilities management were now taken into account tackling a gap in the green operations literature. Having identified the main environmental initiatives in the environmental reports and found their links with activities of operations function, the tables for each green operations practice were populated with the environmental initiatives by Toyota, GM, and

Volkswagen in order to achieve a better visual benchmarking analysis. To check for any possible failures on notes taken during the reading of the environmental reports and their content analysis, searches on the electronic document were carried out by using several keywords for each area of environmental improvement within the operations function. Finally, a paper was written on the environmental reports analysis, which after receiving feedback from a blind reviewing process, was revised and published in the *Benchmarking International Journal* (see Nunes and Bennett, 2010). This provides further evidence of the rigour of the method. Given the nature of the data, the use of qualitative data software was rejected because the environmental reports were very well structured and the PDF files allowed searches within the documents.

With regard to primary data analysis from the case research phase, notes were taken during all interviews. These notes (including observation notes) were developed into case reports where the themes related to the research questions were highlighted and organised into different sections. This structure is visible on the findings from the case research (Chapters 5 and 6). One will note that the ADG case follows a different structure because it was conducted in the first research year of the project, and thereby, it has the structure of the green operations classification. In the cases where it was possible to have audio recording, the audio was revisited in order to complete the report writing alongside the information from observation and the notes taken during the interviews. Once all reports were completed, a comparison was made of the 'stories' about environmental decision making of each case and their relationship with the area where they were being taken. These reports were sent back to the interviewees who had another chance of adding further information or correct possible inaccuracies inherent to the method. In addition, for those cases where there was more than one contact, the report from the previous visit was discussed before starting a new interview. This method was proven effective when dealing with data that mix more than one language. Interviews with translators can create difficulties for transcribing, and besides, the transcriptions would have been of little help since the reports from each interview allowed the interviewees to check on the accuracy of facts and their opinions in a more concise way. The nature of the data and the research, i.e., fact and evidence-based investigation, has also supported the decision of not using transcriptions and software such as N-Vivo. Other researchers who have used such methods were also consulted and their experience was taken into account before making a decision for the chosen method. Alongside with a view from other research practitioners, the theory on research methods has also provided relevant arguments that helped on the decision on the techniques of data analysis.

> "Interviews and other sources for sociolinguistic, phenomenological or psychological analysis generally should be fully transcribed. When nuances of expression are not needed for the analytic purpose of the research (e.g., when what is required from the research is to extract information about how something was done, or a list of relevant issues or indicators), verbatim transcriptions may not be needed; notes from those interviews may be adequate for the task." (Bazeley, 2007; p. 46).

Further studies have also discussed that the use of transcriptions, coding, and qualitative data software in order to help data analysis depend on a number of factors including the nature of the data. Fielding (2004) and Ryan and Bernard (2003) discuss these factors and point out:

> "Since Armstrong et al.'s important study (1997) of inter-rater reliability in qualitative coding, we know that most experienced qualitative researchers code data in rather similar ways. Armstrong looked at a group of medical sociologists, given the same piece of data and asked to code it. They had no

> communication with each other, but they were in the same field, and they came up with substantially similar codes. So I do not have to make a case about the special accessibility of my coding, to say that most people eyeballing the data will come up with some broadly similar themes." (Fielding, 2004; p.102)

> "Still, some of the scrutiny-based techniques (searching for repetitions, indigenous typologies, metaphors, transitions, and linguistic connectors) are best done by eyeballing, and this can be quite time consuming." (Ryan and Bernard, 2003; p.101).

Finally, by using a combination of inductive and deductive logical reasoning method (see Figure 3.4), the results emerged from the data findings in a supplementary manner where each case could provide evidence that responded to the current literature gaps, which were represented by the project's research questions. Metaphorically, the cases' findings and results were incomplete parts like puzzle pieces that when joined formed a final big picture. Because the cases covered different activities of the operations function, it could be said that each of them have their individual value (being difficult to create a hierarchy of the cases in this investigation).

The results of this phase were compiled into two conference papers, and two presentations to colleagues at Aston University. In both cases (conferences and seminars at Aston), there was positive feedback on both written content and methodological aspects. Minor issues related to generalisation and the logical chain of events in the data collection and analysis were incorporated into this thesis eventually. The feedback from both paper presentations were very valuable to check the rigour of the deductive and inductive reasoning method applied since the audience was exposed to research questions, findings, and results.

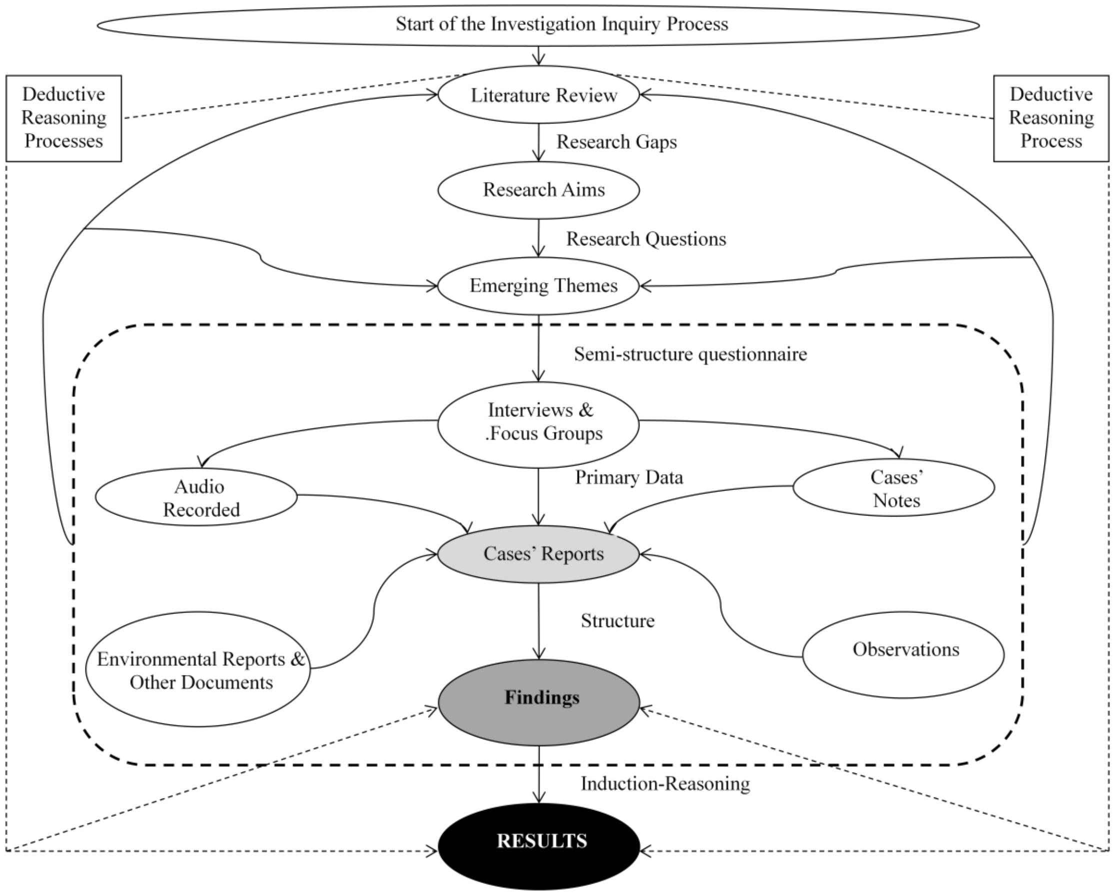

Figure 3.3 – Illustration of Inductive and Deductive Logical Reasoning Process of Data Analysis

The focus group activities run to collect data, test, and evaluate the *GRASS* model were also audio recorded. After populating each activity of the model, the researcher had to run an evaluative discussion of the model in which notes were taken. These notes in conjunction with the audio recording, the evidence from model population, and the participants' opinions (collected in the survey) were used to drawn insights on the model's usability, feasibility, and utility. For this specific case, due to its nature, two types of reports were written, one where the researcher had explicit views about the activities and this information was shared with the participants. Another report was written by the researcher to capture reflective lessons from the observation of participants' decision making processes. Notes on the behaviour of participants, their comments about the activities and to each other during the focus group were documented, as well as aspects of concern that could have influenced the decision making process such as interruptions, openness for new ideas, member dominance, etc. For instance, during the activities, the participants were not using documents such as the University environmental policy that suppose to assist them during the model's population.

To facilitate the data analysis process, the data collected were digitalized and transformed into a JPEG figures and PDF documents. A final version of the populated model was constructed, which the participants found useful in the group meetings, and performance checks. The populated model, written notes, recorded audio, and survey were then investigated to identify the main strengths, and weaknesses of the proposed approach to finally feed into a new revised version of the *GRASS* Model.

3.13 Reflective Learning and assessment of the achieved objectives

Conducting research during a time of crisis is particularly daunting. This research project was first thought from a longitudinal case study approach in which few companies could be assessed for a long period of time and across the whole operations function. The numerous barriers found to stay in the same company for a long period of time was the main reason to rethink the research design. It was a serious issue that could have put the whole research project in jeopardy due to the uncertainty which the companies were operating. Change of personnel, organisational re-structuring, production shut-downs, enormous pressure for cost reduction, and job instability made any attempt at a longitudinal study a certain failure. Two companies that were committed to the research project activities had to step down, one of them because the environmental manager was made redundant during the crisis. The transformation of the Green Operations Framework into the *GRASS* model opened new possibilities for a different research design, and fortunately, the choice of multiple case study research required little change in the original research questions and the project aims.

The multiple case study approach permitted the investigation to cover different brands, and operations in different countries, which although was not thought in the beginning became a real strength for the research. It also provided a research breadth that minimised the problematic issues of generalisation inherent to single case approaches.

Another benefit from developing the *GRASS* model was the flexibility to work with service operations. The roots and purpose of the Green Operations Framework were linked to manufacturing companies. Since the two selected case companies could not participate in the focus group activities for a real environmental decision making conference, an alternative solution was found by using the *GRASS* model with a higher-education institution willing to green its research and teaching products. The university needed a strategy on how to use their current resources in order to introduce sustainability themes in the current curriculum as well as in offering new courses. Furthermore, the decision making conference included environmental objectives on creating impact relevant sustainability research output. Despite the fact no manufacturing organisation was able to use the model, the application of the model in green university products permitted to gain insights on the consistency of environmental objectives and robustness of green initiatives.

Comparing objectives achieved against the ones planned for the project, the results are satisfactory. Gladly, the papers derived from this PhD have received considerable attention in both the academic and industrial communities, which is a good indication that this work was not only relevant but also conducted with rigour. Three other articles will be submitted to Technology and Operations Management journals soon.

3.14 Chapter Summary

This chapter presented philosophical justification for a qualitative study, the research questions and phases, and the instruments of data collection. For the research questions identified, the most appropriate methods were qualitative. The research design, including three main phases, allowed a robust structure for investigating decision making processes within organisations. The findings from each phase are complementary and made it possible to draw conclusions on relevant issues for both theory and practice of green operations.

The next chapter will present the findings from environmental reports analysis and benchmarking. It is strongly related to the development of the green operations framework since the categorisation of practices used is the core of the analysis and framework.

Chapter 4 - Findings from Environmental Reports

This chapter presents the findings from the first phase of the research project. It was structured based upon a classification of green operations that emerged from the literature. Having the classification as a basis for analysis, three environmental and sustainability reports of auto companies were assessed and compared in order to initiate the structure of environmental decision making in organisations.

The main contents of this chapter have been published in the Benchmarking International Journal by Nunes and Bennett (2010).

4.1 Findings from auto companies' environmental reports

In order to identify and analyse the environmental initiatives of the World's major automotive manufacturers, secondary data collection and analysis was undertaken from three companies representing the largest automotive manufacturers in each of the triad regions. Based on their total production of cars and location of their headquarters, the three companies selected for secondary data collection were Toyota Motor Corporation (Japan), General Motors Corporation (USA) and Volkswagen Group (Germany), being in 2008 the largest in each region of the triad. To identify relevant data for each of the companies, an Internet search was undertaken to ascertain their statements about past, current and future initiatives relating to environmental issues within their operations.

The primary analysis undertaken was to consider the “self-declaration” of what the companies were doing regarding their environmental aspects. This was undertaken through the corporate reports and public information on the three companies’ websites. It is important to understand that each company adopted a different interpretation and form of presentation of their environmental practices and initiatives. For this reason any comparisons made between the case companies need to be undertaken in recognition of their business contexts and markets. In this connection their initiatives have been identified using the classification of practices (presented in Figure 2.2 and 2.3), which was originally created with a Green Operations Classification.

4.2 Toyota Motor Corporation

From the website of the Toyota Motor Corporation <www.toyota.co.jp>, which reports the activities of the whole Toyota Group (including Lexus, Daihatsu and Hino), information on the latest environmental initiatives can be found in the Sustainability Report “A New Future for People, Society, and the Planet” (Toyota 2007b). The report is in four main parts:

- Vision and structure
- Environmental aspects
- Social aspects
- Economic aspects

Further supplementary information is provided in the Toyota North America Environmental Report (Toyota, 2007a).

It is evident that Toyota has a wide range of product and process-based initiatives. Starting with "green building" practices, in August 2006 Toyota built the first Leadership in Energy and Environmental Design (LEED) certified automotive dealer facility in USA. This facility uses 20% less energy and 35% less water than conventional structures. These energy conservation measures have led to reduced costs and direct benefits for the dealer. Furthermore, Toyota has included its non-production sites, such as offices, to the scope of its CO2 emissions reduction activities for stationary emission sources. Regarding the manufacturing facilities, Toyota has announced the Sustainable Plant Policy, which encompasses five of its plants worldwide.

Regarding Eco-design, the sustainability report mentions that Toyota is working through various approaches. For engine emissions, it is experimenting with various actions to increase fuel efficiency, introducing technologies to support fuel diversification, and developing clean-energy vehicles. Probably the best-known product development initiative of Toyota is the use of hybrid engines, but this is not a one-path strategy because the company proposes testing other technologies to power its vehicles by alternative means such as electrical batteries and hydrogen fuel-cells, among other options. Toyota has extended its partnership with Panasonic to develop lithium batteries to replace nickel cadmium ones in its hybrid vehicles (Clark, 2008). Lithium batteries, which are currently used in laptop computers and mobile telephones, are much lighter, have a longer life and greater storage capacity.

In order to use eco-friendly parts in production, Toyota is evaluating new materials from renewable resources such as eco-plastics, natural fibre and recycled plastics. Also, it is taking action globally to research methods that will eliminate volatile organic compounds (VOCs) in all vehicle interiors, as well as what are called the “four main substances of concern” (lead, mercury, cadmium, and hexavalent chromium) from all vehicles and their production processes.

Other Eco-design initiatives in Toyota involve improved ease of dismantling and recycling vehicles in response to the emerging legislation in Japan and Europe for end-of-life vehicles (ELVs) and automobile recycling.

More environmental supply chains are created by Toyota’s environmental requirements for suppliers of parts or materials (Greener Supplier Guidelines and Green Purchasing Guidelines) and also by better logistics systems to reduce emissions in urban areas, avoid traffic jams, etc. Toyota has also moved shipments from truck to rail and reduced the number of miles trucks run empty between shipments. Other green supply chain initiatives related to supplier collaboration and logistics include improved packing and reusable metal shipping containers, rather than disposable cardboard and wood pallets.

To reduce the environmental impact from its production sites and processes, Toyota has adopted initiatives such as purchasing of green (wind-generated) power, personnel training on green issues, and reduction and recycling initiatives. Reduction initiatives relate to water and energy, materials and toxic substances. The main source of environmental impact in production is usually the paint-shop, so one of the main improvements was achieved when Toyota converted its topcoat paints to a water-borne type. Similar innovative techniques were applied to reduce VOCs emissions from cleaning solvents through the substitution of conventional cleaning solvents with water-borne types.

By December 2009 Toyota planned to achieve near zero landfill waste at its production plants. Moreover, it has promoted efforts to recycle the entire volume of fly ash generated by its incineration furnaces as raw material for the cement industry rather than sending it to landfill. Also, Toyota has started to evaluate methods for recycling the small quantities of difficult-to-process waste currently being sent to landfill. In order to strengthen environmental responses and at the same time ensure transparency of initiatives, Toyota constantly renews ISO 14001 certification at all major plants and housing works in Japan, as well as in specific areas such as engineering, production engineering and logistics.

In order to respond to the law concerning recycling measures for ELV that came into effect in Japan in January 2005, Toyota has created systems to ensure the proper collection, recycling/recovery and treatment of airbags, automobile shredder residue (ASR) and ozone-depleting gases generated from ELVs. Reverse logistics initiatives have also promoted the collection and recycling of end-of-life parts, working with dealers and parts distributors. These actions depend on, and supplement, the company's Eco-design efforts for dismantling and recycling, thereby ensuring that the final disposal or backward flow of cars and their parts are taken responsibly.

Toyota also claims to take initiatives beyond the operations function by promoting initiatives to reduce traffic congestion through the use of advanced transportation solutions. The company's report reveals that it is pursuing on-vehicle intelligent traffic system (ITS). Other such initiatives relate to environmental philanthropy, education-related programs, environmental protection, environmental research partnerships, and collaboration with society.

4.3 General Motors Corporation

The second company analysed was General Motors (GM). Most of the information about GM's environmental initiatives can be found in its Corporate Responsibility Report 2005/2006 (GM, 2007), which is available for downloading on GM's website <www.gm.com>. This includes initiatives about GM's global facilities, and recycling activities for plants and vehicles of the group brands, namely: Buick, Cadillac, Chevrolet, Daewoo, Holden, Hummer, GMC, Opel, Pontiac, Saab, Saturn and Vauxhall.

Regarding its global operations, GM's Global Environmental Metrics Team has agreed to a common set of metrics for all the company's facilities. These are: energy use, water use, greenhouse gas emissions, recycled waste and non-recycled waste.

Starting with facilities management, General Motors' new Lansing Delta Township Assembly Plant has received a gold certification from the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program. The building is the only automotive manufacturing plant in the world, as well as the largest facility and the most complex manufacturing site, to ever receive any level of LEED certification. In addition, "green building" certification and concepts are being applied to non-manufacturing facilities. GM has also embraced the use of solar panels, installing them on the roof of some of their buildings. Also, for powering its facilities, GM participates in the US EPA (Environmental Protection Agency) Landfill Methane Outreach Programme, a voluntary programme to use landfill gas for plant heating and electrical generation.

GM is also conducting a programme called “Brownfield Redevelopment”, in which the company’s surplus properties are used in many different ways, such as for shopping centres, industrial parks, sports fields and golf courses. As part of its human resources policy GM has initiated the training of personnel in and use of “Design for the Environment” concepts. It highlights that the purpose of such initiatives is to increase fuel economy, reduce emissions, produce safer cars, and promote the responsible treatment of ELVs, with a focus on design for recycling.

Regarding its engines and fuel types, GM addresses this issue with a range of strategies. Continuous improvement of internal combustion engines is claimed to be the short solution to reduce fuel consumption and emissions. Its fuel strategy involves the use of cleaner fossil fuels; compressed natural gas (CNG), liquefied petroleum gas (LPG), biofuels (mainly ethanol), electricity (in the Chevrolet Volt) and, for the long-term, fuel-cells. The development of propulsion technologies and their introduction to the market are planned according to Figure 3.

One of GM’s environmental initiatives at the Supply Chain level is its participation in the “Suppliers Partnership for the Environment” (SP). This partnership joins automobile manufacturers, their suppliers and the US EPA with the goal of improving environmental performance while providing value throughout the automotive supply chain. The transfer of technology is affected by sharing environmental best practices and the creation of a forum where companies can learn from each other. The issues discussed in the forum include design for the environment, environmental performance metrics, and energy optimisation. For instance, SP highlights the importance of economic gains associated with the environmental improvements regarding some supply chain environmental aspects such as packaging, chemical issues, etc.

A similar effort was promoted in China during 2005 to help suppliers to reduce energy, water, and raw material consumption per unit of output, both to make them more competitive and reduce their environmental footprint. GM requires its tier-one product suppliers to have an ISO14001 compliant Environmental Management System (EMS) in place at all manufacturing facilities that supply GM with materials or parts.

Aston University

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Figure 4.1 – Based on the development of propulsion technologies by General Motors (GM, 2007)

All GM manufacturing facilities around the world have implemented the GM EMS that combines elements of the environmental management standard ISO14001 with elements that are specific to GM operations. This overarching management system is designed to drive a continuous performance improvement cycle in line with legal requirements, site-specific objectives and targets, and corporate and sector policies and strategies. Once implemented, a facility's EMS is certified by a third-party accredited registrar in conformance with ISO14001 or the EU Eco-Management and Audit Scheme (EMAS). All new GM manufacturing operations are required to implement and certify their EMS 24 months after the start of production or the date of acquisition by GM. The company runs specific environmental programmes to manage chemicals and to reduce and recycle waste from its operations. Employee training and communication are also on the agenda.

Energy use is being addressed through global reduction targets alongside the increase in renewable sources of energy (landfill gas, photovoltaic and wind power projects).

GM also claims to use water as efficiently as possible and requires that it is treated prior to being discharged. Also, GM says that in all its plants, industrial wastewater is treated before being discharged to municipal treatment plants or other receiving bodies of water, meeting applicable requirements. Where there is no clear discharge criterion, GM applies its own minimum requirements and guidelines as defined by environmental performance criteria that are applied globally.

With regard to GM's efforts to promote water conservation, its report reads:

- Developing a culture of conservation, involving employees, through the Quality Network and ISO14001 program
- Designing water recycling, reuse, and 'water cascading' into our processes
- Installing meters to track consumption in order to drive conservation efforts
- Implementing water conservation projects that also generate good economic payback, such as replacement of once-through water uses by recycle systems and cooling towers.

Regarding waste management, GM applies reduction goals for hazardous and non-hazardous waste at source and, when this is not possible, it reuses or recycles as much as is technically and economically feasible. Performance metrics also cover recycled and non-recycled waste from GM's global facilities. Among the specific programmes to achieve waste reduction and recycling, "industrial oil management", "solvent wipe rags", "ferrous grinding swarf", "battery recharging and reuse", "cartridge filters", "roller filter media", "scrap pallets and wood" are all cited.

In order to avoid air and water pollution from its manufacturing processes, GM has set measures for critical substances, namely NOx, SOx, CO, and suspended particulates. Through the reduction of coal-burning systems, and the increased use of cleaner-burning natural gas, these emissions are being tackled. VOCs also receive attention, so painting and coating processes are using water-borne technology that has low VOC emission. GM also states that it is taking major steps towards eliminating ozone depleting substances. According to the Environmental Performance Report none of its products contain ozone depleting substances, although some of its stationary equipment is still a source.

GM established global goals for CO_2 emissions reduction of 10 percent for the 2005-2010 period. The CO_2 goal is based on an absolute reduction in tons of CO_2 emissions from the production sites. Energy and fuel strategies, and its consequent implications to CO_2 emission reduction, are the basis of GM's efforts against greenhouse gas emission.

Reverse logistics systems in GM, mainly for end-of-life vehicles, are being developed through partnerships. GM claims to be first among U.S. automakers to provide access to vehicle recycling information by posting dismantling manuals on a website <GMAbility.com> (GMAbility, 2008). In Europe, GM has a dedicated group to coordinate the take-back and recycling of its European ELVs. In addition, GM provides dismantlers in Europe with information on all required pre-treatment steps and mandatory components removal via the International Dismantling Information System (IDIS). The system encompasses 448 models, representing 48 brands from 25 automakers. The information is available in over 20 languages. By 2015, the proportion of materials from end-of life vehicles that must be reused or recovered should be increased to 95 percent of vehicle weight. Today GM works together with other automakers on future post-shredder separation technologies (PST) to constantly increase the recycling quota and meet this goal.

Another concern related to ELVs is the use of batteries in GM hybrid vehicles; therefore the company encourages the recycling of batteries and provides a dismantling manual for vehicle dismantlers. Other sustainability initiatives beyond GM's products and production processes are related to nature conservation, human rights in the supply chain, and education programmes.

4.4 Volkswagen Group

The third automaker for which an analysis has been undertaken is the group Volkswagen AG. Similar to Toyota and GM, the primary analysis was based on a report that considers the group's global operations. Therefore, Volkswagen's environmental initiatives should be understood as the group's initiatives and refers to any of its brands (Volkswagen Passenger Cars, Audi, Bentley, Bugatti, Lamborghini, SEAT, Skoda, and Volkswagen Commercial Vehicles).

Volkswagen Group makes available on its corporate website <http://www.volkswagenag.com/> a sustainability report in the publications section. For this paper, the Sustainability Report 2007/2008 "We are moving into the future responsibly" (Volkswagen, 2007) was analysed in order to identify the group's environmental initiatives. The report is divided in five parts:

- Group
- Challenges
- Strategy and Management
- Activities
- Facts and Figures

According to Volkswagen's sustainability report, the main concern related to the construction or rebuilding of production facilities is soil contamination. The group does not mention in this report any initiative regarding green building certification or practices. Moreover, as the autonomous utility companies and non-manufacturing companies (e.g. financial services) are not included in the report, no information regarding the environmental initiatives for buildings such as sales centres could be found.

Volkswagen Group has a maxim for its product and process-related environmental initiatives: "Evolution, not revolution". Thus, its powertrain and fuel strategy is to explore long-term options for non-fossil fuels and to work on improving the efficiency of its existing fossil-fuel engines. The development of innovative technologies for engines and lightweight vehicle designs is in progress. One of the group's brands, Audi, is considered a pioneer in aluminium-based lightweight design. An example of another approach is its partnership with energy and biotech companies. This has resulted in trials of one of its models (the Golf TDI) to operate on Shell GTL (gas-to-liquid) fuel, and Totalflex technology in Brazil, which enables to run a car on any mix of petrol and alcohol (ethanol from sugar cane).

The company report warns that improved efficiency will not be sufficient to mitigate engine emissions as economic globalisation will increase the demand for freight and personal mobility, mainly in developing countries. Confirming the need to go further with enhancing fuel economy, Volkswagen is also experimenting with technologies to power vehicles by natural gas, hybrid propulsion systems, synthetic and biofuels. Fuel cell and electric vehicles are included in the long-term goals. Beyond pollutant emissions, environmental concerns for product development are extended to reduce traffic noise.

Volkswagen Group not only has sustainability requirements for its suppliers but also run training events on the subject of environmental and sustainability issues. Among supply chain initiatives, there are some efforts to minimise the impact of logistics on the environment. The company aims at shifting transport from road to rail and sea. Batch optimisation software is being used to reduce average distances travelled by empty containers. In-house logistics initiatives consider the reduction of use of cardboard packaging, plastics and goods movement to improve efficiency of journeys to stock locations.

Volkswagen’s process-oriented environmental protection work focuses on water and wastewater, air, energy and waste. These are coordinated within internal environmental management systems in combination of standards of ISO 14000 series. Certification of all plants with ISO 14001 is a strategic goal. The company claims to use state-of-art technologies designed to reduce water consumption. Their investments are concentrated on closed-loop systems and the use of rainwater and process water. Efficient treatment processes are used to avoid wastewater contamination as well as improved systems in the paint shop.

Air emissions from manufacturing facilities are being tackled with special attention to greenhouse gases, sulphur and nitrogen oxides, and VOCs. For instance, the processes that precede painting have been solvent-free throughout the Volkswagen Group since the early 1990s. Water-based paints contribute to the reduction of VOCs emission in the company's operations. Energy efficiency is the main initiative to reduce CO_2 emissions from the plants.

Volkswagen has progressed on waste management through the use of advance recycling systems. Recycling is taken beyond manufacturing, mainly in Europe, where Volkswagen has recycling of vehicle in the end of their lives in accordance with European Union End-of-life Vehicles Directive. Alternatives to landfill are presented, including experiences in other countries. In addition to these initiatives, currently 80% of each end-of-life vehicle by weight is already recycled; the remaining 20% goes largely to landfill. However, Volkswagen has developed a new process, which can increase the recycling rate for ELVs to 95%. Volkswagen Group claims to be interested in developing intelligent cars to reduce traffic congestion problems.

4.5 Comparative analysis and discussion

This section discusses how companies portray their initiatives for each green operations practice. It also highlights the differences or similarities in the findings for each case.

Table 4.1 – Green buildings initiatives from Toyota, GM and Volkswagen

	Toyota	GM	Volkswagen
Avoid soil contamination during construction and rebuilding	X	X	X
Green buildings (LEED) certification for manufacturing plants		X	
Green buildings (LEED) certification for non-manufacturing plants	X	X	
Sustainable plant policy	X		
Landfill gas programme		X	
Brownfield redevelopment		X	

Table 4.1 summarises the green building initiatives for the three auto companies. Toyota and GM have opted to certify their facilities with LEED certification in the USA as their reports do not cite green buildings certification in any other countries. The fact that 70% of Volkswagen's plants are in Europe may also explain why Green Buildings certification is not mentioned in its environmental report.

Besides the importance of Green Buildings certification, we found that Toyota is bringing the sustainable plant concept to production facilities in different continents (e.g. Asia, Americas and, Europe) although certification itself seems to be restricted to USA. Landfill methane project, which is an EPA programme and brownfield redevelopment look like an area of differentiation for GM plants compared with Toyota and Volkswagen.

Table 4.2 – Eco-design initiatives from Toyota, GM and Volkswagen

	Toyota	GM	Volkswagen
Fuel efficiency improvement	X	X	X
Fuel diversification development and implementation	X	X	X
Hybrid engines	X		
Flexible engines for the use of biofuels		X	X
Eco-friendly parts in production	X		
No VOC and 4 substances of concern	X		
Dismantling, recycling, and treatment of ELV	X	X	
Intelligent traffic systems (safety, reduced noise etc)	X	X	X
Elimination of ozone depleting substances		X	
Lightweight design			X

Regarding eco-design practices and initiatives (see Table 4.2), all companies seem to have similar ideas towards continuous improvement of the current internal combustion engines. Nevertheless, GM and Toyota have made their message clearer in pioneering the use of a new generation of clean fuels and the most advanced powertrains. Toyota is the pioneer with hybrid engines and GM has already publicised its intentions of having an electric plug-in car (Chevrolet Volt) while Volkswagen states its intention of evolution rather than revolution. Volkswagen uses “totalflex” technology in Brazil, which allows its cars to use both ethanol and petrol (gasoline) in any proportion. GM cars also have this feature in Brazil. Similar to the case of the USA on green buildings, we identify the importance of context playing a role, since car manufacturers in Brazil have developed the totalflex technology for the host market but have not extended it worldwide.

What is clear to note from the product-based initiatives, especially those regarding the choice of fuel and powertrains, is that the companies are investing in competing technologies. The main reason for this is the lack of certainty about the future of alternative fuels for cars, particularly in the short term. It is not clear which environmental strategy companies will pursue with regard to fuels, i.e., will they have a standard product such as an electric car for the global market? Or will they choose to use different technologies for different countries?

As a result of the complexity and uncertainty involved, Toyota and GM seem to be taking the risk of trying everything to wait and see what will work better. This strategy may allow Toyota to pioneer the technologies however, their leadership will come at a high cost.

Table 4.3 – Green Supply Chain initiatives from Toyota, GM and Volkswagen

	Toyota	GM	Volkswagen
Green supply chain policy	X	X	X
Transfer of environmental technologies	X	X	X
Use or shift to railways	X		X
Efficient transportation	X		X
Reduction of packaging, chemicals, cardboard, wood pallets, etc	X	X	X

Table 4.3 shows the commonalities between GM, Toyota and Volkswagen when it comes to greening their supply chains. Deeper supplier relationship (requirements, guidelines and training), better logistics and concerns about packaging are the main streams. However, both Toyota and Volkswagen highlight their concern about empty containers, trucks and shipping mileages, which is not mentioned in GM's report. Likewise, Volkswagen and Toyota's documents refer to the use of railways, which could be an influence of the European and Japanese contexts that offer efficient rail networks. As in green buildings initiatives, certification seems to be an important factor for GM, as it requires most of tier-one suppliers to have ISO 14001 environmental management systems.

Table 4.4 – Green Manufacturing initiatives from Toyota, GM and Volkswagen

	Toyota	GM	Volkswagen
Certification of all major plants with ISO 14001	X	X	X
Zero landfill waste policy	X		
Alternative energy and cleaner power systems	X	X	
Water-borne paint shop	X	X	X
Personnel training for process-oriented improvements (water, energy, emissions and waste reduction)	X	X	X
State-of-art technologies for water conservation			X

Table 4.4 presents the initiatives for greener manufacturing processes. Similarities are noted between the three auto makers relating to water-borne technologies for the paint shop, and the ISO 14001 certification for major plants. Toyota focuses more on its zero landfill waste policy and purchase of green energy. The scarcity of landfill and Japan's dependence on imported oil may play a role in the environmental initiatives for production.

GM promotes the ISO 140001 certification of all of its plants and as well its landfill gas projects. The EPA policy of providing incentives may be an important driver for this company's green manufacturing initiatives.

On the other hand, Volkswagen highlights its process-oriented initiatives and the state-of-art technologies to reduce water consumption and waste discharge. For the German manufacturer, certification of all plants is also a strategic goal. A further investigation would be necessary to understand the role of European context for developing expertise in green technologies focused on water. Table 4.5 will present the analysis for reverse logistics.

Table 4.5 – Reverse logistics initiatives from Toyota, GM and Volkswagen

	Reverse logistics		
	Toyota	GM	Volkswagen
Compliance to ELV laws and directives	X	X	X
Advanced recycling systems			X
Bring recycling rate to 95% of vehicle weight		X	X
Ozone-depleting gases from ELV	X		
Collaboration with dealers and parts distributors	X	X	

Table 4.5 summarises the reverse logistics initiatives from our cases. From the reports, it seems companies are legislation-driven and the product recovery issue is also being dealt with by the design team (e.g. initiatives such as design for recycling, dismantling, etc). Major efforts are related to end-of-life vehicles and particular components such as air bags. Toyota specifies its concerns with components such as

airbags and ozone-depleting gases from ELVs and the role of dealers and parts distributors in the product recovery network. GM's report highlights its response to European legislation and its goals related to reusing and/or recovering materials as well as the dismantling guides. Volkswagen's report mentions its concerns in avoiding landfill and developing new processes to increase the recycling rate. The scarcity of landfills in Europe and Japan may contribute for the development of advanced technologies by Toyota and Volkswagen.

4.6 Chapter Summary

Currently the critical issues related to Green Operations Management are the complexity embedded in life-cycle analyses and the concentration on efficiency gains. These two major issues have increased the need for systemic approaches. The work of Bertalanffy (1972) highlighted that modern technology and society have become so complex that the traditional branches of technology are no longer sufficient, so approaches using a holistic view or systems thinking, and of a generalist and interdisciplinary nature, become necessary. This is no different in green operations if the aim is to have effective design, implementation and analysis of practices and initiatives that truly drive modern economies towards higher levels of sustainability.

Investigating what companies are doing currently in terms of environmental initiatives enables academics and practitioners to reflect on strategies that could lead to better results. The identification and analysis of these initiatives are the main practical contributions of this paper. Nevertheless, it is only the first step. In this study, the authors were concerned about gaining a broad picture of environmental initiatives in the automobile industry. As far as the limitations are concerned, the most important of these is the selection of the companies, which was done using production volume and country of origin as the principal criteria. There is ample evidence that other, smaller, companies are pursuing more sophisticated and original environmental initiatives (Wells and Orsato, 2005; Williams, 2006; Williams, 2007). However, studying these three largest companies of the triad provides an interesting start to building a roadmap of environmental initiatives in the industry. Also, there are limitations regarding the use of secondary data in the form of the environmental reports. Therefore, we have investigated what companies say they do; not necessarily what they actually do. Strategic initiatives may not be divulged for confidentiality reasons, and, for various reasons, the reports might contain information that is not actually implemented as reported.

The main conclusions from these environmental reports can be summarised by highlighting the main initiatives undertaken by the three automotive companies rather than making a comparison between them. The world's largest car manufacturers are adopting environmental practices from the construction of their manufacturing plants to the end-of-life of their products.

Green building certification is being used for both production sites and non-manufacturing facilities. Both Toyota and GM have taken the opportunity of using "green power" to reduce oil dependency in their plants through the use of landfill gas, wind and solar energy. CO_2 emissions were also tackled by substitution of cleaner fossil fuels for coal.

The design of the cars is considered a key activity for addressing environmental concerns through its ability to affecting the whole life of the product. Initiatives in design vary from lightweight material, fuel efficiency and diversification, elimination or reduction of VOCs and the “four substances of concern”, and also intelligent systems to reduce traffic congestion. Design for recycling and dismantling are the main approaches to deal with landfill shortages and new stricter ELV legislation.

Supply chain management has included environmental initiatives with three basic approaches: selection of suppliers, transfer of technology and more efficient logistics systems (e.g. packaging, reduction of empty container travelling, etc).

All three of the companies studied have addressed the main environmental impact of manufacturing through technology-based solutions. Paint shops were converted to water-borne types and water-based solvents were also introduced in the processes. Energy and water conservation, reduction of greenhouse gas emissions, waste management (including recyclable and non-recyclable waste), and recycling are the main initiatives in production.

The increasing use of batteries (in the hybrid vehicles), new electronic components and safety devices may produce forthcoming concerns for reverse logistics. Currently, stricter ELV legislation (e.g. in Europe and Japan) are regarded as a learning process, which provides the company with experience to help governments and environmental agencies to design new types of legislation, mainly in developing countries.

Generally, because Toyota, GM and Volkswagen are all global players, they can take advantage of being under a stricter regulation to be the first mover or environmental leader and keep ahead of the regulation in other markets. This applies mainly for construction of new production sites, plant emissions, brownfield redevelopment, engine emissions and ELV.

By analysing the environmental initiatives in the automotive industry we see a pattern which can be used as a lesson for other sectors. Firstly, the environmental initiatives were confined to the manufacturing processes, then these were expanded to product performance, supply chains, non-manufacturing facilities, and recently to more responsible final product disposal. Closer analysis shows that they are trying to move from being reactive to proactive, extending control over other activities in the supply chain, and therefore taking actions into a more uncertain and intangible context of their businesses.

Similarly, other industry sectors will face such evolution. This could happen first by drivers such as legislation, competitors, customers or environmental advocacy groups. Yet, these pressures will be taken over the most critical part of the supply chain, which will differ from industry to industry. The electronics sector is an example. Due to the toxic substances in batteries, there is a requirement for correct product disposal before the demand for green building certifications has emerged. On the hand, in the garments and clothing industry, the fragility aspect is the suppliers' subcontractors due to the non-conformities with the industry ethical code. In the end, companies that want to be in the forefront of environmental leadership will need to take care of the whole operations functions rather than isolated activities. Under this perspective, our categorisation of Green Operations Practices will help them in taking environmental decisions strategically and expand their initiatives beyond the manufacturing processes.

In summary, this chapter provides evidence from secondary data about how automotive companies are tackling their environmental challenges. The research findings on how their environmental decisions are made, the origin of the ideas for improvement and the drivers for environmental practices are covered in Chapters 5 and 6. In addition, the framework structure used in this chapter to benchmark the companies' environmental initiatives is represented in the Green Operations Framework presented in Chapter 8. This conceptual framework intended to help the environmental decision making process within these Green Operations Practices having an Environmental SWOT analysis as its starting point.

Chapter 5 - Findings from case study research in the automotive industry

This chapter presents the findings from case study research conducted within a sample of seven car manufacturers. As mentioned in the methodology section, the unit of analysis considered in this study was decision making teams, or the decision maker himself (or herself).

Still within the automotive industry and in conjunction with the conclusions from the environmental reports of car manufacturers (Chapter 4), this research examine primary data from interviews and focus group activities to draw conclusions upon the difference and similarities between environmental decision making processes across the operations function. A semi-structured questionnaire was used as the main data collection instrument. It has included the investigation of issues related to drivers, origins of ideas, and structures of environmental decision making in manufacturing, product development, supply chain management, and reverse logistics departments.

The pursuit and selection of the "appropriate" interviewee was given by the composition of the sample according to the Green Operations Practices categorisation used to benchmark environmental reports (Chapter 4).

5.1 Case 1 – Japan Motor Company (Green Supply Chains)

This is a Japanese-owned company and the investigation took place in a plant operating in Thailand. The Thai plant is regarded as one of the most environmentally-friendly of the Japanese Group (JG) worldwide since it has had environmental concerns from its design and construction phase. The Thai plant uses advanced technologies for facilities, manufacturing as well as corporate social responsibility initiatives. Here, the company is referred to as the Japan Motor Company (JMC), which is part of JMC Asia Pacific Engineering & Manufacturing Co. Data for this case study were collected through two interviews with the Environmental Manager and her assistant (see Table 3.3.) Each interview took approximately 2 hours.

Participants' profile at JMC

Two employees of JMC were interviewed. The first interviewee was the manager for the Safety and Environment Promotion Office at JMC, who had been with the company for 14 years at the time the interview was conducted. Her main responsibilities concern the creation of the long-term environmental policy and adoption of the JG's management philosophy, values, and methods in the plant. She also had responsibilities for developing JMC plant's long-term plan and action plan, as well as to distribute it to all plant sites in Thailand.

The second interviewee, the Environmental Management Assistant, had been working in the company for three years – with the main responsibilities involving the Asia Pacific environmental committee and supply chain activities.

Environmental initiatives and their drivers at JMC

The Environmental Manager presented the JMC environmental initiatives. According to the company's 2008 sustainability report, it has three main areas for environmental initiatives: sustainable mobility, sustainable plant; and sustainable society. Sustainable mobility focus on alternative fuels (Bio Diesel, Ethanol-E20, hybrid and NGV) and the development of technologies for JMC vehicles. In the sustainable plant initiatives, it is important to highlight that the JMC plant in Thailand is one of the five Sustainable Plants of the group in the world. This eco-construction and operation policy includes activities in energy saving, renewable energy utilization, and forestation implementation.

The interviewees explained that JMC differs from other plants because it was the model of sustainable plant policy. It is an eco-plant because it had environmental concerns incorporated from the initial design stage. So from the start, the JMC plant had high-tech equipment, energy co-generation, use of efficient water treatment systems, solar panels, and reforestation in the area – which other plants would not have had.

Still within the sustainable plant concept, the environmental initiatives have been expanded since 2005 to all areas of the business: production, logistics, suppliers, and social contribution.

JMC's environmental vision plays an important role. Hence, the plant initiatives are aligned with goals such as zero emission policy and CO_2 stabilisation. In logistics, JMC looks for decreasing distance, using transportation hubs and increasing carriage capacity to reduce the number of trips, and the energy consumed in transport. In some logistics activities, transportation uses vehicles running on natural gas in order to reduce emissions. The goal was to reduce emissions by 10% in 2010.

Regarding the development of a sustainable society, JMC has social and environmental activities at both local and national levels like the "Stop global warming project", which passes knowledge about global warming to schools.

The Environmental Manager indicated that the main driver for the environmental initiatives is the JMC environmental Policy. In her words, "We have to achieve the company-wide environmental policy that we have established. The top management is very important. The top management pays full attention to this (…) We have to report to them every 6 months. The top management gives the main direction and motivate us. They want us always thinking of the environment like continuous improvement."

Besides the internal policy, the other main driver is global warming. Interviewees explained that JMC wants to be the number one in environmental performance, while keeping ahead of legislation, competitors and keeping their customers and the local community satisfied.

The Environmental Management Assistant explained that the government may start buying greener cars in 2011, and it is also an incentive to implement environmental initiatives. The Environmental Manager added that JMC tries to minimise the environmental risk in plant projects.

Over time, both interviewers have experienced stricter targets for environmental performance and the expansion of the initiatives from the internal operational activities towards the supply chain. So, as part of the future trends, JMC will expand its environmental values to suppliers and dealers, and eventually, the

Environmental Manager sees social responsibility as part of the sustainability initiatives, including ‘ISO 26000:2010: Social Responsibility’ certification. Actually, these initiatives are already in course and are in the data collection stage, i.e., the first step to produce a proposal with suggested initiatives to be approved and taken by JMC top administration.

“Since 2007, we have the responsibility to collaborate with the suppliers. Our suppliers are now part of the Company group division of Asia Pacific, not only under the JMC responsibility”, explained the Environmental Manager. The group trains its suppliers to reduce emissions through practices such as energy savings and kaizen. The Environmental Manager indicated that the suppliers need to understand about Kaizen itself, and start analysing their processes to find out the weakest point and what they can implement to improve their environmental performance.

Suppliers are also encouraged to use the group production system concepts such as *muda* to cut unnecessary steps in their processes. *Muda* is a traditional Japanese term for an activity that is wasteful and does not add value. The group suppliers receive training in the beginning of the contract and set a model plan of best practices for suppliers. Then, they are required to provide reports and attend a 2-hour meeting every three months involving more than 200 suppliers.

For the dealers, JMC applies the DERAP – Dealer Environmental Risk Audit Programme – which looks at environmental improvements at dealers’ facilities. DERAP is explained further below in the green supply chain section.

Origins of ideas at JMC

Most of the ideas in JMC come from internal sources as the JMC team is composed of scientists and engineers. This mix in the team (scientists and engineers) is able to develop the ideas; but the JMC also seize on the training, policy, and culture as part of a powerful worldwide automotive group. There is also partnership with Non-Governmental Organisations (NGOs) such as TEI – Thailand Environment Institute.

Decision making process at JMC

In JMC, decisions are taken in a step-by-step approach. The departments are autonomous to generate ideas and present them in an approval load to the general manager. Most of the work is done in teams. If an idea requires a high investment, it is sent to Japan to receive headquarters approval; otherwise, it is dealt internally. However, there is also allocation of budgets for large projects run by the department such as "Stop Global Warming", which received 15 million Bahts per year (approximately £3 million).

Only regarding projects for energy consumption reduction, 12 million BATH in projects were approved.

Main decision criteria at JMC

Projects in JMC Safety and Environment Promotion Office are evaluated based upon two main criteria: (i) the break-even point, Return Over the Investment, and (ii) the impact on the environment. “Many projects do not meet the break-even point criteria, but we implement because the social contribution”, says the Environmental Manager. The solar panels in the case plant are an example. JMC environmental image also plays a role in the decision.

Depending on how the budget is organised, i.e. if the budget concerns to other departments (e.g production), a feasibility study is done considering the different departments’ perspectives in order to approve the project in conjunction with the Safety and Environment Promotion Office.

The JMC Safety and Environment Promotion Office does require some help in some projects. However, these needs are very dependent upon the project characteristics and objectives.

If a project involves high technical knowledge, e.g. combustion systems, JMC receives help from consultants (e.g from Japan or from Thai universities). For example, an academic from Japan is the consultant on the Eco Forest project.

The basic structure to develop an idea into a project is as follows:

i. Proposal: a basic idea on what is the project about
ii. Approval from organisation: formal support from top administration
iii. Objective: the aim the project should achieve
iv. Targets: the goals the project should achieve
v. Description: the problem statement, and the context of the project
vi. Project Break-down Structure: the work packages of the project
vii. Responsibility: the responsible people for each work package
viii. Reasons: the justification for project implementation
ix. Schedule: the project timeline
x. Budget: the project cost

The Environmental Manager explains how important it is to negotiate beforehand with other departments to have an idea approved in the company before proposing it to the top management. In this respect, she said: “This is very important. We need to study and investigate together (with other departments) first before presenting a proposal.”

Green Supply Chain Initiatives at JMC

Local suppliers that are under responsibility of JMC are classified in four types: parts, materials, facilities, and logistics. Global suppliers are under the responsibility of the Japanese Group (JG).

From 2001 to 2006, suppliers needed to meet two basic requirements: (1) to have ISO 14001 certification and (2) to reduce or eliminate the four substances of concern (Pb, Hg, Cd, Cr6+). As evidence how environmental issues at supply chain level are becoming more and more important, the group now requires enhanced environmental performance, social and environmental contribution activities, reduction of packaging material, and CO_2 materials, besides ISO 14001 certification and the substances of concern. For these criteria, JMC establishes targets that the suppliers will need to meet.

The plant is located about one hour by truck from Bangkok. Most of the suppliers are located nearby the Plant in Thailand around 1-hour radius. This is aligned with JG's JIT policy to have short transportation time. Within the JG's policy, suppliers will also be required to report their social contribution activities going for sustainable investments and therefore beyond philanthropy and charity actions.

Dealers are managed through the Dealer Environmental Risk Audit Program (DERAP). According to the main DERAP requirements, dealers should: (1) have an environmental team, (2) comply with the law, (3) implement environmental policy and communicate it to the community, (4) manage hazardous waste, and (5) treat waste water. Special attention to the dealers is also related to the CFC emissions due to cars air conditioners and air bags. Interestingly, the Environmental Manager explained that these requirements are not part of the ISO 14001 requirements.

In Thailand, there is no regulation for end-of-life vehicles; hence, there is a lack of recycling facilities in the country. As a consequence, JMC focus on the eco-design only to minimise the environmental impacts from final disposal of its products.

In Japan; however, the group has already started working to increase recyclability of vehicles.

JMC is also preparing its suppliers for eventual end-of-life regulations. The final disposal concerns reach the daily lives of employees at JMC in attitudes like using rechargeable batteries in their offices. The Environmental Manager highlights the fact that in Thailand the cars stays on the road for 10 to 15 years, therefore, the second-hand car market and used spare parts is very active.

Although there is a lack of recycling plants in Thailand, the JMC plant follows zero landfill policy in its waste management programme.

Performance measurement at JMC

JMC manages environmental performance of its production and non-production sites. The environmental performance measures are cascaded from the site level to production cells and even specific equipment. For suppliers and dealers, the environmental performance is informed and monitored within the Green Purchasing and DERAP Guidelines.

The environmental performance of products during its use is not the responsibility of the environmental management department in Thailand, because it belongs to the research and product development teams based in Japan. Nevertheless, the Environmental Manager highlighted the fact that the car production in Thailand is going through improvements in fuel consumption and diversification, mainly to use ethanol.

The JMC case's contribution to theory of Green Operations

The investigation examined green supply chain initiatives at JMC. This case provides strong evidence of how internal policy affects environmental decision making. With regard to the financial viability, a number of uncertain initiatives were implemented as experimentation to reduce emission (e.g. solar panels). More interestingly is the fact that JMC operates with a sustainable plant policy in Thailand where there was a later development for environmental initiatives such as the implementation of ISO 14001 standards by local companies. These initiatives represent the importance of internal policy in the selection of environmental solutions.

This case also reveals the company's intentions towards designing greener products. JMC was actually aiming at securing governmental purchases in 2011, rather than the individual personal mobility market only.

Much can be learnt from how the various initiatives were justified by JMC's Safety and Environmental Promotion Office. While manufacturing-based initiatives could be easily justified in terms of saving money and reducing pollution; only a few manufacturing-related initiatives were implemented with the support of internal policy makers. Two elements are identified for the environmental objectives of JMC: (1) to reduce environmental impacts and (2) to support business strategy. The support to business strategy can be understood by the enhancement of a socially responsible image, experimentation of greener processes and product, etc. Manufacturing-related initiatives, including the greening of up-stream supply chain, are seen with a good balance of profitability, reduction of pollution, and better environmentally-friendly image.

5.2 Case 2 – Waltham (Green Manufacturing)

This case is based on primary data from two personal interviews with the Environmental Manager (EM) as well as secondary data from corporate reports, including internal environmental reports, and a plant tour. The duration of each interview was around 1 hour and 30 minutes, which added to the 1-hour plant tour gives a total of 4 hours of in-company investigation.

Company and interviewee profiles

The case company is a British luxury car manufacturer that is part of an international automotive group. It has been given the fictitious name of "Waltham" to the company and "Popular Cars Group (PCG)" to the automotive group it belongs to for confidentiality reasons.

The EM has been working at Waltham since 1977. He has been responsible for several departments in the past as maintenance engineer, plant engineer, and technical engineer. He became the Environmental Manager at Waltham in October 2007.

Waltham is one of the major local employers and in 2008 the company's production exceeded 10,000 cars. In the factory, the production of highly customised cars in low volumes creates a combination of factors that, together with the company's employment benefits, keeps the attendance rate for employees (or "workers") to 97.7%. The level of customisation reduces the amount of repetitive work and the low volume, coupled with high quality, although requiring enormous attention, demands less physical work and pressure from the assembly line workers.

The employee turnover at Waltham is around 3% per year. An internal report shows that manufacturing facilities occupy 50% of the covered area of the plant, i.e. 70,000 m^2 out of 140,000 m^2. The total site area is 335,000 m^2.

There are few robots used in production and most of the work undertaken in assembly is done manually. Car bodies are manufactured and painted in the plant, however the press shop is located in another city. The factory also produces two types of engine, the W8 and W12. These are both cylinder piston, internal combustion, engines that are very powerful and used in various luxury cars of the auto group, which Waltham belong to.

According to the EM, Waltham had little to be proud of regarding its past environmental performance. A combination of old facilities and infrastructure (mainly out-of-date equipment) did not help the company in its figures for harmful emissions. Although much has improved over recent years, the plant is still close to the local council's permitted emission limits. The EM believes that Waltham has improved a lot its environmental performance and awareness over the last 20 years.

An Environmental Management System (EMS) is in place, and the company has moved from a situation of simply legal compliance to a more ethical and environmental position. "In the beginning, the main drivers were legal compliance and cost savings. Some of ethics and environmental issues were a motivation. Now, ethics and environmental argument has become top of the reasons for what we do" (EM).

The EM further explained that his current role is to make Waltham's Environmental Management System (EMS) meet its environmental objectives and goals.

Drivers, justification, and support for actions at Waltham

A milestone for the environmental initiatives taken by the company was its acquisition by the Popular Cars Group (PCG) in the 1990s. Although PCG Principles were only formally applied to Waltham in 2007, the initial investments (£120 million) contributed considerably to the alterations in the plant, and therefore to its environmental improvements. As Waltham is still repaying PCG for its investments, PCG has a major influence on what Waltham does today.

The justification for environmental initiatives includes the need for more efficient technologies to achieve better environmental performance, mainly to stay ahead of the environmental legislation (the city council's emissions limits), rapid return on investments and cost reduction. Also, being part of an international group raised awareness about benchmarks and environmental management systems standards.

For example, the ISO 14001 EMS was implemented in 1999 and the reasons behind this initiative was basically because it was the standard across the globe, as well as the best system Waltham could have for controlling the environmental aspects in the plant. In the early 1990s, Waltham was producing around 1,400 cars annually, mostly old models under the roof of an ageing infrastructure. At that time, the company was facing financial problems, so the environmental technologies and initiatives needed to have a good return on their investment.

Further to the involvement of PCG in Waltham's strategic decisions, an important adjustment for environmental projects' payback time broadened the horizons for "green" investments. The payback was extended from two years (still used for “normal” projects) to five years. This would play an important role as the teams previously had to be very intuitive about how an environmental investment would perform over such a short period.

Process of environmental decision making at Waltham

Regarding the decision making process, the decisions are usually undertaken by hybrid teams. The EM indicated that these teams are composed of “appropriate people” (i.e. people whose department is related to the decision). For instance, maintenance, environment, small projects and production planning are often among the departments that have representation in the decision making teams. So far, a structured approach is not adopted to take environmental decisions, although an improvement model is in the course of being introduced in order to aid the strategic and operational decisions.

The improvement model is still in a conceptual stage but it seeks to integrate strategically the engineering and business plans. Also, the model should take into consideration short-term activities such as recycling, energy saving and materials as well as long-term leadership action to make Waltham a credible green company.

Origin of ideas at Waltham

The ideas that result in environmental initiatives at Waltham come from different sources: external consultants, in-house experts, local teams and a PCG “best practices database”. External consultants are more involved with strategic decisions and highly specialised technical solutions for operations (e.g. they are also used in the implementation of new technologies). On the other hand, local teams participate in waste minimisation challenges to identify potential savings in the plant regardless of their department.

Those local teams are involved in a programme called “Environmental Champions on Site”. For instance, in production, teams have a monthly meeting to present “ideas to save”. According to the EM, this changes peoples’ behaviour, not only in the top administration but everywhere across the company. As a concrete result it was estimated that £120,000 per year was saved in energy costs due to the environmental champions’ challenges.

In addition to these sources of ideas, a survey is also used to foster and collect environmental initiatives. From the suggestions, some ideas are selected to be implemented based on the decision criteria previously mentioned.

Environmental Initiatives, performance measures, and benefits at Waltham

Waltham has held an ISO 14001 EMS certification for more than 10 years. The EM indicated that he had primary responsibility for Waltham meets the Popular Car Group‘s Environmental Principles and for maintaining the certification status. He also revealed that Waltham has joined the PCG group database for knowledge sharing recently and as a benchmark Waltham scored higher than some of the other PCG units.

Environmental initiatives in Waltham include ISO 14001 EMS, and minimisation of CO_2 emissions, water usage, energy utilisation, and waste generation.

Besides CO_2 emissions, energy, water and waste, there are other key performance indicators for the plant, such as green travel and car parking.

More specifically relating to Waltham's manufacturing processes, the paint shop uses water-borne systems to reduce to use of solvents. Some of the key processes have individual metering to check their environmental performance, e.g. those that emit Volatile Organic Compounds (VOCs) or use solvents etc.

Investments in boilerhouse technology have proved effective combining better environmental and operations performance. It allowed a reduction of fuel consumption by 31% from 1999 to 2006, even though a second shift was started in 2002. In addition, despite production having increased by more than 500% from 1998 to 2007, the total energy used was reduced by 28% and energy used per car by 86%. Following a similar pattern, absolute plant CO_2 emissions were reduced by 23% while plant emissions per car fell by 85%. Table 5.1 shows the improvement achieved by the plant over the period 2000 to 2007.

Table 5.1 – Figures of Waltham for change in production volume, total CO_2 emissions, emissions per car produced, total water consumption, water used per car and total waste produced between 2000 and 2007 (from Waltham's environmental report 2007)

Aston University

Illustration removed for copyright restrictions

Waltham's 2008 status within PCG recognises these environmental achievements and the legal compliance of permitted processes.

With respect to Waltham's future strategy, its short-term goals include a further reduction in plant carbon emissions per car by 20% compared to 2006 levels through continued cross functional energy team activities.

Waste management is another important programme in Waltham's EMS. An environmental goal of making 85% of all waste go to recycling or for reuse purposes rather than landfill disposal was established for the 2009 year. In 2008, this rate was around 65%. Another example of waste management is provided by the recognition of the value of leather as by-product. All the leather waste is commercialised and sold locally. Also, total waste recycled has increased by 66% in comparison to 2006.

Waltham's Environmental Strategy 2008-2017 encompasses its long term goals under the motto to be a world-class sustainable manufacturer.

Together with the environmental concerns, there are goals for health and safety issues. The company had an 85% reduction in incidents between 2001 and 2006, which reflects a highly positive approach to the management and control of onsite environmental aspects.

The Waltham case's contribution to the theory of green operations

This case reveals interesting organisational issues to the implementation of green operations practices. First, it shows that when the ownership of the company changed, so did the internal policy. In the 1990s, although the company was operating in a developed country, the fragile internal policy associated with little investment capacity did not have a good environmental performance. When it was taken over in 1998 by the Popular Cars Groups, the change of internal policy led to the implementation of environmental initiatives as the investment capability grew.

From a theoretical perspective, it is very interesting on how the company could easily find win-win environmental initiatives in the early stages of environmental decision making. Although the literature usually considers environmental initiatives as win-win solutions (e.g. reduces environmental impacts and production costs), this case brings evidence that sometimes companies will need to visualise green operations initiatives beyond the standards of other financial investments. Here, the case company extended the ‘normal’ 2-year pay-back time to approve projects to 5 years when considering environmental projects due to their strategic value.

Third, an important fact brought to light from the investigation in Waltham was the use of group data-base as a source for environmental solutions. The knowledge management of environmental ideas and solutions is a fact that increases the value for a company to be part of an industrial group.

Last but not least, this case shows also how companies with low production volumes as well as poor environmental performance are able to have significant reduction of emissions, despite the increase in production volume over the years (See Table 5.1 on page 164).

5.3 Case 3 - German Premium Cars (Eco-Design)

Five employees of German Premium Cars (GPC) participated in the focus group activity in Germany. The purpose of the focus group was to understand the drivers and origin of ideas for environmental initiatives as well as the process and structures behind the environmental decision making. The focus group took two and half hours, and for language reasons a German facilitator fluent in English was invited to assist the activity in case of English being a barrier for the German participants to express themselves clearly.

Profile of focus group participants

Table 5.2 shows the participants (identified by letters for confidentiality reasons) and their profile at GPC.

Table 5.2 – GPC's focus group participants and their profile

Participants	Profile
A	25 years working at GPC, responsible for locking mechanisms, leader of the group of locking systems
B	2 years working at GPC, responsible for small motors, window lifter, and interface with suppliers
C	11 years working at GPC, responsible for development and construction of automatic systems, power boot systems
D	24 years working at GPC, responsible for coordinating of purchasing
E	2 years working at GPC, responsible for designing power boot systems
F	Assistant facilitator, 2 and half years consultant in logistics and production, interface with supplier management

Importance of product development to produce green cars at GPC

GPC understands that the main issues related to greening the product are directly related to reducing weight of the car, as well as reducing cost simultaneously. The group feels a strong pressure from top administration in order to accommodate customer requirements and increase car sales. They see the green agenda as a strategic issue that need to be incorporated in the business:

One participant points out: “What we are trying to do here is to earn money, to sell cars; and what helps us to sell cars now is the CO_2 discussion and marketing.”

Alongside with the marketing issues, the product functionality and specifications are on the mainstream too. As a premium car manufacturer, GPC also noticed that greening the car is important to provide a good feeling for their customers, and not to be seen as a major polluter.

However, one participant highlighted the importance of the legislation for taking action. He reveals that there was no pressure to change things before the legislation. For example, the substances of concern (e.g. lead) were only removed after it became a legislation requirement. “It costs money for us to do it differently”, added a participant.

For them, it will happen the same with CO_2 emission in the near future. As the incentives are brought to the market and governments push manufacturers to produce cars within lower emissions limit, customers include green features in their purchase decisions. On the other hand, when these issues do not reach customers, it is harder to include green features. They give the example of the US market where the incentives to produce more economic cars is not high due to the low fuel prices.

When asked, the focus group participants listed the elements below as the main drivers for taking a greener approach in product development:

- Internal policy
- Legislation (specifications)
- Functionality
- Customer
- Profitability
- Workers' conditions

Participants were asked to rank these drivers in terms of importance; however, they said this task was very hard because the product needs to meet the different requirements from these drivers at the same time. When referring to the relationship and conflicts between these drivers, the main conflict considered was the cost of producing a green car and the customer's expectation: "Customer wants a green car, but doesn't want to pay for it", says a participant.

The focus group participants give a recent and concrete example of one of GPC's models that was built to introduce green features, including an aluminium body. The model was produced from 1999 to 2005. They believed the car failed to be sold in the market because it was too expensive and introduced in the market too early (when green issues were not very well regarded by society). Similarly, the participants thought that the marketing strategy was not well developed and the economic crisis could have played a role.

What is a green car at GPC?

This part of the focus group reveals that initially the participants have difficulties in defining a green car. A number of concepts are raised, including the conflicts between a green standard car and a green premium car. The participants tended to consider cars not generally green products. The current debate about green personal mobility enabled participants to compare the environmental performance of GPC cars against popular cars and even other modes of personal mobility such as bicycles.

The discussion is also directed to the sales issues. “A green car is what the customers want”, said one participant, adding that “It would not be green to produce cars that cannot be sold in the customers’ perspective”. The group understands that a green GPC car should consume less fuel as possible, emit less pollution as possible, while providing a good feeling for the customers when driving it.

The participants demonstrate a conflict on what is a green car, for them as a private user and a GPC employee. The focus group participants discussed their own mobility needs and the role of GPC as a business in offering premium cars for a market that desires and buys them. On the one hand, there are issues related to the essentiality of functions and features of cars as a means for mobility - and in the discussion, the group indicated that they may not need a GPC car to go to work every day. On the other hand, there are other factors regarding the greenness of the car that are related to the green technologies it develops, safety issues; etc.

Participants also brought the discussion of the importance of the image of the company and the integration and importance of green to its reputation. GPC informally benchmark with other industries and brands to find out the differences and relationship between environmental performance, legislation, customer requirements, and industry segment.

One participant points out the difficulties for new product development: “it is very hard to define a new GPC whether it will be green or not”. The definition of a green car is mainly driven by an official (legal) decision (by public authorities) about its environmental features. This participant’s explanation is founded on the fact that new concerns can be discovered about the materials used or how the car interacts with humans and the environment after the design process is concluded. So there are several features in the new car that the level of information about them is not well-know before and during the design process, hence, a green car can suddenly become not green.

How does GPC define a green car company?

Regarding the production processes, the discussion is around more tangible issues such as certifications, emission, toxic substances and so on. Here, an employee perspective is also included without major conflicts by identifying that a green company also improves employees’ work conditions by eliminating toxic substances or through changes in the work ergonomics. However, the participants highlight the need for integration of product and process to define what is a green car company. For instance, green can be even extended to a car that avoids accidents.

Issues related to absolute (total) emissions and emissions per car, energy consumption, water treatment, materials were discussed. The impact of customer requirements and legislation on the production system was also highlighted. For instance, all GPC plants in Europe follow the same strict legislation; however, due to the strong competition and costs, participants were not entirely sure whether GPC would implement environmental initiatives if the company is not pressured by law.

Although with more tangible aspects than the previous discussion about the greenness of the product (cars), some participants were not so clear about what is a green car company either. A green car company can be seen as a company that takes the best possible environmental initiatives or judged by absolute emissions.

Participants shared the idea that going green may increase production costs sometimes, although they previously pointed it out as an opportunity for cost reduction.

Environmental initiatives in GPC product development team

The product development team at GPC are responsible for four main streams:

- Legislation compliance
- Fuel consumption reduction
- Elimination of toxic substances
- Green supply chains

GPC is trying to reduce fuel consumption and emissions through car weight reduction; what makes the group to say that “green equals weight.” Participants affirmed that there is pressure to make most components lighter. Ironically, while components get lighter, cheaper, and smaller, the car is filled with more components adding more challenges in the product design, as well as in the final goal of reducing total weight and fuel consumption. Issues related to packaging were also associated to reduction of size of components.

Elimination of toxic substances has happened both by proactive and reactive behaviour. For instance, elimination of toxic substances has taken place in the car handles, and the substitute technology was cheaper than the previous application. However, elimination of Chrome 6 adopted by suppliers cost more money which is passed to GPC.

Within the theme of green supply chains, GPC has environmental criteria for selecting and working closely with suppliers. These criteria are included in the GPC specifications and VW group standards, which defines forbidden material and processes.

Participants also indicated that once minimal criteria are met, including non-environmental criteria, they could choose the cheapest supplier unless it goes against the company's quality standards. The focus though is mostly on car emissions rather than the total emissions in the car's life-cycle. The changes adopted by GPC to reduce weight in the product are not related to reduction of emission in the supply chain, e.g, a lighter material may use more energy to be produced and emit more pollutants than a heavier one during its whole life-cycle.

Fuel consumption reduction in the end is being achieved by reduction of weight, changes in tyres, and improvement in the car aerodynamics

Participants also commented that the importance of environmental issues has been growing over the time. It has gained much more attention than 10 and 5 years ago, being a very important factor for the business in the last two years.

Where do ideas come from at GPC?

In terms of product development, ideas are generated internally, with some intervention from the VW group through its concept catalogue. Internal competition is an important source for ideas according to the participants.

Depending on their capabilities, suppliers can be a relevant source of ideas and alterations in the product components. Acquiring ideas from suppliers or allowing them to do modification in components of the product is a matter that needs to be aligned with quality and strategic purchasing. If the supplier is involved with competitors or other car manufacturers, GPC may not allow them to take responsibility for product component change to avoid the risk of losing product differentiation in their premium cars.

Competitors are also a source of ideas mainly through benchmarking. GPC will consider competitors environmental choices when facing a decision with various alternatives.

Environmental decision making structures at GPC

Taking environmental decisions in product development requires considerable effort. One of the first steps is to identify and synchronize the decision to the connected parts, and then, prepare a proposal to be presented and approved by a committee. The committee includes people from different areas such as production, product development, and finance, with top managers being able to provide input.

Environmental issues could be the main driver for environmental improvement in product development as in the case of the handles. But it is naturally a multiple objective decision as the transformation to be greener should be done achieved in conjunction with achieving cheaper, lighter, and smaller products.

Just like any other business decisions, environmental decisions are susceptible to the organizational structures and internal power. A decision to change a component can take three to six months, only to be approved without considering the time for searching the possible solution and preparing a proposal to be presented to the senior and top managers.

Although there have already been many different tools being used at GPC, the participants indicated that they would like to use a tool that could help them in making complex decision, including environmental decisions. "Sometimes the tools we have are more a barrier than, something to help", said one participant.

Another participant described how a tool could be beneficial for GPC: "The tool should help the decision makers to better classify a concept: green or red; 0 or minus 2… This could be used for process, material, recycling and so on…" Other characteristics were also mentioned:

"It needs to fit on a sheet of paper." (Participant C)

"It needs to bring definitions. This special tool should help us in preparing the environmental proposals – today; there is no tool for a unity of green concepts as we have FMEA to avoid risk" (Participant E)

Because of the lack of a process or a tool, there are no criteria apart from the legislation when designing components for the car, as weight and size are indirect measures of environmental performance. Nevertheless, the tool should focus on process rather than technical issues as they may change for each component. Issues related to behaviour change of employee in adopting new processes and values in the product development were also raised.

Regarding the process of taking the decision on product development, participants revealed that they are pressurised to have new ideas that fulfil the three basic criteria (lighter, cheaper, and smaller). If this happens, they are able to proceed and transform the idea into a proposal. There is no formal requirement for greener ideas but to meet the current legislation.

All in all, ideas to be implemented need to go through the following stages; preparation of the proposal, evaluation, approval of the proposal, and finally, the implementation. It usually takes three months in research and preparation, and if the idea is well received by the committee, it may be evaluated and approved within three months; otherwise, it can take much longer in a process of refinement and resubmission of a proposal.

This procedure demonstrates that product development workers are responsible for finding ideas and preparing proposal; but not autonomous in the decision making process. The chances of having a new idea approved are reduced if the idea is not completely aligned to the organisation's main goals, overall strategy or corporate philosophy.

Participants could not predict exactly the impact that new, emerging and stricter take-back legislation would have on their work. However, they speculated that it is currently impossible to meet a possible legislation asking for 100% recycling of cars. Regarding the use of recyclable materials, again the company takes the legislation as the main driver, as it already happens. Participants indicated the reuse of parts or recyclable/recycled and remanufactured parts is something not feasible for GPC due to market reasons.

The environmental performance of the components is evaluated by different measures as each component may have specific features. For instance, the standard is to have lighter and smaller components; but electric devices may also be evaluated by their energy consumption. The measures are taken considering the whole life of the car, which can include particularities of where the car is being driven.

Other initiatives on the car propulsion systems include start stop systems and hybrids engines. These topics were not discussed in depth.

The GPC Case's Contribution to the Theory of Green Operations

This is a case with particular importance to the theory of green operations due to limited empirical research reported in the literature on eco-design, specially, for the automotive industry. A number of issues have emerged from the focus group with regard to the decisions for greener products.

Firstly, there is a clear understanding in the company that eco-design is a strategic issue and that eco-friendly features can help to sell cars in the future. Therefore, there are pressures coming from the top administration; however, the support for actions is not necessarily in the same intensity. The product development team realises the possible costs and risks to produce greener vehicles. These are reflected in the drivers to go green. The ultimate decision and actions tend to come when legislation requirements are about to take in place. In fact, there is a major difficulty in defining what a green car is. The level of complexity around the subject is high and the previous experience of the company plays a role in the sense that producing "greener" cars that do not sell cannot be considered a green design. The complexity of conceptualising a green car is given. This is because of the intangible characteristics intrinsic to the product and the factors that are not under the company's control such as drivers' behaviour, urban infrastructure, amongst others. Also, due to the level of complexity, there is a high level of uncertainty related to eco-innovation at the product level. Considering the relatively new investigations on the theme and the limited amount of information available, it may not be possible to predict what is green in five years time; thereby, companies may face an awkward situation of choosing materials or technologies which are considered green today but may not be considered green in a near future. Paradoxically, by doing nothing, avoiding the risk, and not facing the uncertainty can also negatively affect the company's image; so, despite of the risk, complexity and uncertainty, companies that want to lead in environmental performance will need to invest in green product development.

Secondly, and more related to the decision making process itself, is the way criteria is built into the decision making process. Mostly, cost is the order-winner and environmental and other non-environmental criteria are likely to be qualifiers. The qualifiers however, are considered as thresholds that after being achieved, cost becomes the main criterion for the team's decision.

The third important issue around green product development is related to procurement activities and supplier relationship. The team's decisions are strongly affected by the context where the suppliers operate. They may not collaborate, give autonomy, or even share greener design for components with suppliers if they also supply for competitors and/or possible interventions on component quality. Here lie the challenges for using outsourcing as the means for higher environmental performance.

Finally, the decision making within the product development team is presented to be very bureaucratic and without a clear structure for the introduction of environmental criteria or concerns to product design. Again, the complexity of environmental issues for product design makes the environmental performance measurement very difficult and dependent upon the perspective taken for reduction of environmental impacts. While a life-cycle approach may embed even more complexity to the decision since it will include uncontrollable factors, a component analysis approach (energy consumption, weight, size, etc) may be too narrow to justify the environmental gains.

5.4 Case 4 – Auto Group of Deutschland (Green Operations)

Purpose of the visit and interviewees' profile

The purpose of these interviews was twofold: (1) to gain a general view of green operations decisions at plant level and (2) to analyse the use of Green Operations Practices and decisions at the production plant, particularly, the landfill gas project, because of which Auto Group of Deutschland (AGD) received the US EPA[1] award recently.

The Environmental Manager at AGD/USA was the main interviewee to understand the plant's environmental initiatives and the landfill gas project. The Communication Manager provided a broader view of the plant and group initiatives. As the energy supply is a critical aspect for the operations function, the equipment service employee in the Methods and Standards Department was also interviewed with regard to the operational stability of the landfill gas turbines for the system.

Introduction to the AGD case

The AGD facility in the USA was established in 1994 in the city of Spartanburg in state of South Carolina. It occupies an area of 2.5 million square-feet; with half of this area already built. The factory operates two production lines and manufactures two different cars (a SUV and a roadster) in five different models. The plant exports its products to 120 countries around the world.

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1 **EPA stands for Environmental Protection Agency** (see www.epa.gov)

AGD chose upstate South Carolina because it offers numerous resources. South Carolina has a state wide Technical Education System that is key to developing a qualified workforce. Spartanburg is also in close proximity to necessary transportation facilities, such as the deep water port in Charleston, and its centralized location in the Southeast benefits distribution to dealerships.

AGD Manufacturing requires a large supplier network to provide the necessary components to build a vehicle. Around 190 companies make up the extensive supplier network that supports AGD. In order to reduce costs, AGD encourages its suppliers to move closer to the factory and fortunately, many have. Fifty of its suppliers are located in South Carolina, 49 are located within a 2-hour drive radius from the plant. Thirty-nine suppliers chose to place new operations in South Carolina to partner with AGD.

All the engines come from Germany or Austria by ship, and are then transported by truck to the factory in South Carolina.

The production plant in Spartanburg is 70% automated, has 4,500 workers and the two production lines produce more than 600 cars per day. The factory operates five days a week, working two shifts with four hours between them. The factory need to meet at least 90% of the daily production plan, otherwise overtime is used to accomplish the daily target. There are teams of six to 10 people around the manufacturing floor, which make possible to rotate jobs and reduce physical and mental stress for the workers during the work day. Although the level of automation is reasonably high, and computerised inspection is utilised at the end of the line, people are considered very essential to produce a high quality vehicle that meets the specifications. Each car has around 2,000 check points executed by assembly line workers.

The paint shop, which was the first water-based paint shop in USA, has capacity of 280 car bodies per batch. This facility is 100% automated, having 365 robots. The production schedule is produced after orders and payment are received from dealers. Moreover, every car has a bar code that informs the customer in which stage of production his/her car is.

The SUV model takes 30 hours to be produced, while the roadster takes 24 hours. Each batch spends approximately 10 hours in the paint shop. Considering inspection and other activities, the total time of a car in a factory is circa 3 and half days.

The factory receives 30 to 38 deliveries of components per day from its suppliers with parts only stored in the warehouse for between two and four hours. The just-in-time system forces suppliers to be closer to the facilities and deliver the components on time. If the parts are delayed, the supplier pays a $7,000 penalty to AGD. Most of the components come from ship to the port, and then, by rail to the factory.

100% of the energy used in the paint shop comes from the landfill gas project. The project supplies 63% of the total energy used in the plant and saves $1 million per year.

Green operations at AGD-USA

Sustainability has been part of AGD's strategy since its start. AGD was the first free CFC manufacturing plant as well as the first automotive manufacturer to use water-based paint shop in the USA. These facts happened in the early 1990s. Since then, considerable effort has been made at AGD in order to manufacture high-quality cars and reduce the environmental burdens of their processes. Today, the whole group has ISO 14001 certification, which is called the matrix certification.

Green Buildings at AGD-USA

The plant in Spartanburg is located in a considerable green area. Trees and ponds are part of the site amongst the manufacturing plant, the company museum, and the Performance Centre. The plant does not have Green Building certification by LEED because of some of the materials used do not meet the necessary specifications. However, AGD has a good indoor environmental quality and goals established to reduce water and energy use. Assuming the LEED criteria for Green Buildings, the following aspects of the plant were analysed: the sustainability of the site, efficiency on water and energy use, resources and material management, indoor environmental quality, and innovation and design techniques.

The production site is located between Spartanburg and Greenville on the motorway (about 25 minutes from the city centre of both cities). As there is no access to the plant by public transport, the company provides collective transportation for its workers. Still regarding the sustainability of the site, as some components come from overseas, the infrastructure of a deep water port, railways, and motorways provides a good balance for inbound logistics. Also, the proximity of suppliers increases the sustainability of the site. As the major market for its products is the USA, the sustainability for outbound logistics is also strengthened. It is important to mention that some of the aspects of Green Buildings overlap with Green Supply Chains or Greener Manufacturing practices. Thus, the aspects related to supplier relationship and logistics are described below in the section on Green Supply Chain Practices. Practices relating to water and energy efficiency are discussed in the Greener Manufacturing section.

Considering the resources and material management of construction and operations of the building, concrete from demolishing and waste from construction is used in the site to avoid soil erosion. The rain water is also collected and used for the irrigation of the gardens.

The cleanness of the plant gains attention in the mid of its machines and provides a good level of indoor environmental quality for the workers because it is associated with a comfortable temperature and adequate illumination.

Eco Design for a Greener Product at AGD-USA

Indeed, most of the efforts made by AGD are towards greener processes. Nevertheless, the Communication Manager revealed that there were ongoing projects in Germany, where AGD teams are working towards high-technology advanced diesel engines that would emit fewer pollutants than the current hybrid engines used. Other aspects referring to a greener car that would bring a system which transform the kinetic energy into electricity, store it in a system that would allow the car to shut down for small time (like in front of a red light on the street) and re-start using electricity. It is called start-stop system. The Communication Manager revealed that there was some scepticism about the system, but the company was convinced by the engineers that the effect of multiple shut downs in a car fleet would conserve a significant amount of energy, and therefore contribute significantly to overall pollution reduction.

Due to AGD's strategy to produce luxury cars, having quality, power, and comfort as priorities; there are some limitations to the use of alternative materials and fuel, as well as improvements in fuel economy. Actually, AGD has a strong reputation and discloses information about the use of Design for Recyclability and Disassembly. However it was not possible to obtain information about those initiatives because all cars are designed in Germany.

Green Supply Chains at AGD-USA

During the interview, the Environmental Manager endorsed the information provided on the company's website about AGD's initiatives on greening the supply chain. Environmental concerns are taken into consideration when selecting suppliers. Around 43% of the parts used are supplied on a JIT basis by the many suppliers located around the Spartanburg area. Many of AGD's suppliers were required to obtain ISO 14001 certification otherwise they could not continue doing business with the company. There are actions implemented by AGD to stimulate suppliers to enhance their environmental performance; although there is no formal programme of environmental technology transfer.

AGD offers an interesting example of greening the logistics system. For a long time, some imported parts and components were overwhelmed by the use of protective material, mainly plastics and wood, generating a significant packing waste.

A smart decision comes through when the environmental team realised that the transportation methods were reliable enough to avoid the use of protection material. The environment benefits of eliminating the packing were associated with economic gains since the costs of repairing the rarely damaged parts were lower than the acquisition costs of plastics and wood used for protection.

AGD outsources some of its logistics activities. For instance, TNT Logistics provides AGD its warehouse services. Actually, outsourcing these activities to companies with expertise in those processes tend to enhance effectiveness on distributing, handling and so on. Therefore, outsourcing to companies focused on logistics operations might also be considered as an alternative way to green the supply chain.

Greener Manufacturing and the Landfill Gas Project at AGD-USA

The Environmental Manager explained that many environmental initiatives are integrated with other programmes implemented by other departments. Non-manufacturing departments at AGD also adopted the 4-Rs philosophy of reducing, reusing, remanufacturing and recycling. For instance, the cafeteria serves 700 people every working day and uses biodegradable cups. Moreover, the final disposal of the solid waste from the cafeteria is at the landfill that generates the methane that the factory burns to produce electricity and heat. The environmental programme for energy conservation has a strong link to the six sigma quality programme. Together the teams are working to reduce energy consumption per car produced by 30% by the year 2012. Continuous improvement efforts lead the environmental programmes, thus, even for water, which is considered a cheap resource in USA by AGD, there are goals for consumption reduction. The six sigma programme foster initiatives to identify opportunities to reduce waste, mainly those related to energy use.

The AGD plant in Spartanburg got a green reputation from its birth. The company's headquarters in Munich decided to establish the most technologically advanced paint shop in Spartanburg and the first one in the USA. The main environmental benefit was the reduction in the emissions of Volatile Organic Compounds (VOC). As environmentally-sound solutions need to satisfy quality and profitability constraints, the water-based paint shop also avoided investments on pollution control equipment and a better coverage to the car bodies. Today, Spartanburg houses the oldest paint shop of the group and 100% of the energy used on the paint-shop comes from the landfill gas project.

Regarding the concerns to human health and safety management (HSM), one of the HSM programmes at AGD is the use of function rotation amongst the workers. This prevents lesion of repetitive efforts and improves the ergonomics in the work place ensuring the quality of the products.

The company measures the environmental performance of its manufacturing process through several indicators such as: total water used, process waste water, air emissions, energy consumption, CO_2 emission, solid waste, and chemical waste. The unit of analysis is based on per car produced and the indicators are measured monthly. The plant is partially autonomous to implement projects since those projects that require up on 500,000 euros need approval from the German headquarter. This was the case of the landfill gas project. The idea of using landfill gas in AGD's operations came from the US EPA. Interestingly, this fact brings a new perspective on sustainable innovation as the current paradigm of competitive advantage sustains that innovation should come inside-out and be difficult to be imitated.

After US EPA approached AGD in 1999, the project was sent to Germany for approval, and after receiving the green light from the headquarter, the group spent the next two years planning, searching for partners, and finally, in December of 2002, the turbines were burning landfill gas.

During the planning phase, AGD had in mind a very clear picture that it is a car manufacturer and it would not be strategic to address people issues and put effort into activities of the project that AGD did not have expertise in. Thus, long-term partners for construction and operation of the power plant needed to be found. Indeed, there were barriers to implement the project, but the major challenge was the lack of technical knowledge about the operations of an energy supply system considering that energy is one of the most critical inputs for the manufacturing plant.

Dresser-Rand, a German company, provided the gas turbines and the technology to power unit at AGD the plant. Ameresco designed, built, and became the owner of the pipeline, gas processing and gas compression facilities, which connect the Palmetto Landfill via a 9.5 mile pipeline to AGD's manufacturing facility. Since completion, Ameresco has been managing the overall operations of the project. What is more, Palmetto Landfill is the gas generator in the project, which basically shows how each partner in this project was focused on their core competences. Again, outsourcing is one of the strategies used to green operations.

The landfill gas project enables AGD to reduce its emissions by 60,000 tons of $CO_{2,}$ saving the company $1 million every year. Having four turbines producing electricity and heat for the plant from the combustion of methane generated from waste also gave them operational stability from the financial perspective. AGD signed a 20-year contract, which guarantees costs reduction and price stability for its operations. However, the Equipment Services employee explained that the landfill gas is produced organically and composed of 50% of methane (CH_4), producing 530 BTU per cubic foot. Due to these facts, it may vary its gas supply during the day, therefore, new system is less reliable than the former using natural gas (90% of CH_4), which produces 1,000 BTU per cubic foot. Although this operational instability does not create major difficulties, AGD keeps a "back-up" system to inject natural gas and maintain the pressure and energy supply to the plant.

The contract considers that AGD needs to have a minimal take of gas and the payment is according to energy unit. Nowadays, the turbines supply energy to co-generate approximately 4.8 MW of continuous electricity and 2,100 gallons per minute of hot water at 270 degrees Fahrenheit, being responsible for almost two thirds of energy used at AGD plant.

In short, the reasons for choosing the landfill project rather than other projects were its economic and environmental benefits, and also the image of AGD towards a sustainable business management.

Reverse Logistics at AGD-USA

Unfortunately, the initiatives related to collection, treatment and disposal of end-of-life cars could not be evaluated during the visit; although the AGD group has incorporated in the product development phase the techniques of Design for Disassembly and Recyclability. There are indeed management of backwards flow in the production processes and reuse of some of the resources, mainly in transportation (e.g. wood supports).

Environmental SWOT at AGD-USA

In chapter 8, a Green Operations Framework is proposed. The starting point of the Green Operations framework is an Environmental SWOT analysis. *AGD-USA* was the only case where this approach was tested because it took place before the incorporation of systems thinking in this PhD study. Focusing in the threats and challenges, the environmental manager was able to clearly list the future threats and the challenges for AGD:

- Problems related to new car models – it is very daunting to a new supplier to adequately meet these requirements;
- Plant air emissions – rates of ozone and particulate material emissions are close to the standards allowed by South Carolina State;
- Total solid waste – As the production increases, new technologies are needed to cope with solid waste increase over time;
- Water use – water tends to gets scarce and more expensive, so more efficient water systems may be necessary;
- The goal of reducing by 30% the energy consumption in 2012.

It was possible to note that AGD is taking opportunities on green operations practices to improve its environmental performance, and its strengths are process-based. The weaknesses may be product-based as there are limitations to improve environmental performance of luxury cars.

AGD-USA Case's contribution to the theory of Green Operations

The case study at AGD provides supporting evidence for theory building of green operations on various issues. Firstly, there is an integration of sustainability in the business management agenda. The landfill gas project and the water-borne paintshop system improved environmental performance and overall profitability of the company. Another evidence of strategic environmental management from the case is the fact that AGD's corporate image was also one of the reasons to implement environmentally-sound projects. Indeed, it was again a strong environmental internal policy that allowed the company to take forward a large project that was strongly related to operations sustainability.

Secondly, this case has also contributed to the theoretical discussions about the role of environmental protection agencies and their relationship with businesses. The landfill gas project is an example of how the USA EPA embraced the role of stimulator of environmental solutions beyond the mere regulation, command and control role. This fact demonstrates how environmental agencies can assume a new role beyond command and control, and work together with the private sector to identify opportunities and develop win-win solutions for companies and local communities. The landfill gas project also demonstrates the strategic use of outsourcing to make large environmental projects viable.

Thirdly, due to its large scope, the AGD case-study shows that environmental-leading companies are likely to excel on green manufacturing operations first before extending their environmental initiatives to logistics, facilities, supplier relationship, product design, and end-of-life. The case company brought into the U.S.A a new benchmark for automotive paint shop that was being used in Germany. The experimentation and benefits pushed the industry to new standards on manufacturing sustainability. Nevertheless, limited environmental performance differentiation could be identified at the product level and in other aspects such as supplier relationships and end-of-life vehicles.

Last but not least, there is a lesson for innovative companies: environmental innovation means new suppliers and new challenges. By developing new environmental initiatives, the company consequently needs to adapt its supply chain, develop or create new suppliers; and acquire new partners that may involve significant risks. These risks may relate to developing new green supply chain practices, meeting stricter requirements and the transfer of environmental technology. Establishing medium and long term relationship with suppliers, integrating sustainability philosophy, and sharing knowledge may be difficult tasks to be managed with new suppliers for various reasons including Intellectual Property Rights.

AGD’s efforts for a sustainable business management have been recognised by its history of winning a number of environmental awards, namely: being part of Dow Jones Sustainability Index, EPA Green Power Leadership Award (Energy Partner of the Year) and the National Ambient Air Quality Standard (from South Carolina State). Possibly, the most important message of these awards, and AGD’s efforts towards sustainable operations, is the elimination of the barriers and paradigms that sustainability and profitability are mutually exclusive, in particular, to large projects. On the contrary, they both must become part of a long-term corporation vision. Recognising this integration may favour the company's position against competitors, and enrich its image to the customers. The Environmental Manager stated in the interview the relevance of sustainable practices for AGD: "We have sustainability in our heart, and we do this to increase our profit today".

5.5 Case 5 - Birmingham Luxury Cars (Eco-Design)

Purpose of the case

One two-hour interview was conducted at the Sustainable Mobility department at the company here identified as Birmingham Luxury Cars (BLC) (fictitious name due to confidentiality reasons). The purpose of this interview was to analyse the factors and implications of environmental initiatives for product development in one of the manufacturing plants located in Birmingham (UK).

Introduction to the case and profile of the interviewee

The interviewee is current design engineer (DE). He has been working in the automotive industry for about 12 years. His educational background is in engineering and he started as an apprentice in 1996 in a SUV manufacturer in Britain. Most of his time was spent in new vehicle development at the design and concept department. DE worked there until he moved to a luxury car manufacturer in 2000 and in the same year this company was bought by an American group, which also owned the SUV manufacturer, and he was again part of the same automobile group. The new ownership started managing the SUV and luxury cars manufacturers' operations under the name of BLC. He worked in the luxury car division of the group for two years. From 2002 to 2004, he worked for a department that served both brands of BLC, called "Architecture and Strategy". During that time, He was mostly involved with design of BLC cars and his role was to identify architecture and chassis that could meet engineering requirements.

Environmental initiatives and their drivers at BLC

Between 2004 and 2006, the “Architecture and Strategy” department was transformed into the “Advanced Product Creation” department. At the same time, due to some pressure from advocacy groups such as Greenpeace and Friends of Earth, this new department started to undertake environmental issues into the product development activities. Most of the environmental-related actions related to weight reduction in order to increase fuel economy. At that time, BLC’s Chief Engineer was dealing with the lobbies from those environmental groups.

In 2005, the “Sustainable Mobility Group” (SMG) was created. In 2009 it has 50 people. The interviewee (DE) became part of the group in 2006 and his role is to look after the use of hybrid applications for a SUV model. Hybrid applications refers to a joint platform that different models will share in Europe, allowing different models to share not only assembly lines but also components. There are two basic types of hybrid applications: micro hybrid, like the “start and stop” systems, and full hybrid, which combines “start and stop” with electric and petrol modes. Full hybrid technology allows the car to operate on the electric motor alone, the gasoline engine alone or both together. Another important aim of his work involves the need to meet Premium Light-Weight Architecture requirements in the vehicle design.

DE perceived most of the environmental initiatives of BLC regarding product development due to his position in the company. He said that because of the Kyoto Protocol and the new European Union legislation some environmental technologies are being pursued. However, because BLC produces vehicles in low volumes, there is high pressure to deal only with the core issues of the company and it is difficult to develop new environmental technologies internally. Thus, most of what is done at

BLC aims at avoiding to be very far from the competitors and meet the legislation. “Our size and volume does not allow high investments in R&D, so our best choice is to look at clever design possibilities and reduce the car’s weight – This is a “free” solution that reduce costs, improves fuel economy and creates benefit to our customers”, explained the interviewee.

At the company level, DE knows that SUV vehicles have a carbon off-set scheme to compensate the emissions of the first 100,000 miles of every SUV sold by the company.

Other environmental initiatives of the BLC’s actions are the use of recycled commodities and reduction of harmful material, which are both also driven by legislation. For him, there are basically five main drivers for the environmental initiatives at BLC:

- Image and customer perception
- Security of supply
- Fuel price
- Legislation
- Competitors’ actions

The interviewee explained that due to the unique choice of producing only SUVs, BLC may benefit with carbon trading with other high volume manufacturer of smaller cars. “The scary thing is “image and customer perception” because we want to continue to be the best perceived off-roader”, said the interviewee. DE continues:

> “We are a limited-resource company. It does not pay us to lead. We look at what competitors have done, what is available for our suppliers and at

legislative reports. Then, we analyse the options based on cost of the technology, Return of Investment (ROI) from customers, market requirements, image versus legislation, CO_2 emissions reduction, and fuel economy. We look at the reduction of NOx and particulate materials too, but CO_2 is the biggest one. It is the major contributor for the decision. We are also moving to have an approach that uses more life-cycle analysis (LCA)."

DE believes that the company does not have enough resources to invest in green-leading technologies, and this role does pay-off for them. He has also said there are other developments influencing the environmental performance of the cars such as: aerodynamics, better lubrication, reduction of resistances in the engine and to make the pistons to run easily.

When asked how the change in the customer behaviour had affected the company, i.e., an increasing number of off-roads being used in the urban centres instead of off-road, which as initial purpose of the car (military use in difficult terrain), DE said that the company will keep the same core competence (the best 4x4) but will deliver a different message: "The car needs to continue having its breadth of capabilities, durability, and high standards. The environmental attributes are to be competitive too".

Green cars and the origin of ideas at BLC

DE's perception of what is a green car company needs to be associated with what the company delivers. For him, a green car company produces small vehicles, with light weight, low powered engines, and high fuel economy. "They would probably need to run by electricity or biomass fuels". Later, he refered to the company’s operations and the need of environmental concerns in manufacturing, use of solar panels, and capture of rain water.

The Designer Engineer said the environmental performance measures he knows refer to CO_2 emissions of the fleet. He feels that there is considerable pressure from the top administration on the SMG to identify suitable technologies for the future. Most of the ideas come from suppliers, competitors’ actions, and universities. “The truth is that we are running late for the party. We do have technical experts to try to develop technology and governments are giving grants to develop and implement them; but they need to assure the necessary infrastructure.”

DE understands that the importance of environmental issues have increased last five years but mostly related to CO_2 emissions and humanitarian actions. “We are also looking at LCA in product development, seeing what materials could be used, the choices we have and the selection of suppliers”, said DE.

DE believes that a green operations model to take environmental decisions need to use life-cycle analysis and a priority systems. He further emphasised that “It needs to consider marketable actions, things that the customer can see and benefit from. It needs to analyse not the costs and the price you can sell, but also the loss of sales of not doing it and the investments required to implement it”.

Case’s contribution to the theory of green operations at BLC

This case is particularly rich for green operations theory building. The main reason for its richness is the fact that the case company found several barriers and difficulties in integrating environmental issues in the business strategy. The nature of the product and the lack of a clear environmental strategy contributed to conflicting goals between higher levels of sustainability and short-term profitability.

The early stages of environmental initiatives were triggered by pressure of environmental advocacy groups, legislation, and finally, competitors' actions. Although operating in a developed country, which supposedly would provide infrastructural support for higher environmental performance, the vacuum of a proactive behaviour and internal support policy led to severe implications to the progress of sustainability actions in the company. First, with the intention to improve its corporate image and alleviate customer pressures, BLC opted for end-of-pipe solutions which tend to be less effective and more expensive alternatives. The lack of more cost-effective environmental initiatives at the process and product design phase could have brought both higher environmental performance to cope with external pressures and profitability to support future investments.

Second, the size of the company and the nature of their main products (off-road vehicles) made difficult to visualise the opportunity behind sustainable initiatives as well as anticipate external pressures. Although the company has developed a worldwide well-known R&D department and leading with safety technologies, very little was done to seize upon those design competences in order to align sustainability to the business agenda. The interviewee understands that the time lag to embrace sustainability had an impact on the actual environmental performance of the company. More critical, perhaps, is the lack of strategic directions that put the sales in jeopardy – it becomes clear in this case that environmental issues are indeed strategic and needs to be thought beyond opportunity costs and short-term payback analysis.

Understanding the future implications and their impact on business, including future sales, development of learning and innovation competences is critical. Without a clear environmental strategy, it will be very hard to position the company well against competitors and ahead of legislation.

5.6 Case 6 - Birmingham Luxury Cars (Green Manufacturing)

This is a second interview within BLC is with one of the company's Project Engineer (PE) at the Advanced Manufacturing Engineering department. Although in the same company as Case 5, this needs to be considered a different case as the unit of analysis is the decision maker or decision making teams. The former case focused on the product while this one investigates process-related issues. The purpose of this interview was to evaluate environmental initiatives and decision making structures in the Advanced Manufacturing Engineering department of BLC, which includes the purchase of manufacturing equipment.

Participant profile and role in the organisation

The PE of BLC worked for a different luxury car manufacturer in UK until January 2002. Within 12 months of being there, the company merged with a SUV manufactured brand. Since the PE's work involved interaction with a number of other departments across the group, he saw himself as a BLC employee since the beginning of the merger.

Since 2002, the PE has worked in the areas of: Quality Management Systems (auditing) and Business Systems Development. He is currently involved with the Advanced Manufacturing Engineering (AME) department. Within the Quality Management Systems, his work included procurement support to achieve the goals of the Ford Production Systems, and the issues of Reliability & Maintenance. He is also a member of the quality management steering committee and the environmental improvement steering committee. In addition, he has also managed the audit schedule for the ISO 14001 environmental management system.

His work has always been focused on the facilities' machinery, tools, and equipment. As a result, most of the procurement activities that he is involved in are related to the purchase of production lines rather than product components. His role is to support the procedures, documents, and forms in the AME department. The AME department supports all production technologies (painting, stamping, body construction, and trimming) and its activities are aligned with both quality and environmental management. Furthermore, there are legislation compliance issues that are the responsibility of the AME department, such as the EU directives on waste segregation and elimination of ozone-depleting gases in the air conditioning system.

Importance of environmental issues at BLC

PE believes that sustainability and environmental issues have always had a relatively high importance within the organisation; however, the nature of the importance has changed over time. For instance, in engineering level, they always needed to meet safety specifications and meet environmental group standards within a cost constraint.

PE believes that naturally and genuinely people will try to do the "right thing", for example, in choosing lower energy intensive process, etc. But now, there is more attention in the market to what is going on from the consumers and the media's perspective. Therefore, the company needs to inform consumers about what they do, provide product information, etc.

Furthermore, PE says it is an evolutionary process in BLC - and same things that were done in the past are different now. He added:

> "We always needed to do an environmental impact assessment upfront, but now as a function we need to go beyond than filling up forms for the group environment department standards were calling for, so we use far more sophisticated metrics and records, including from an auditing point of view".

PE explained that the ownership changes had an impact on the company culture, and as a consequence on how the company deals with environmental issues. So BLC has inherited production systems control procedures and management practices from the American automotive group (the previous owner). He also explained the role of standardised procedures imposed by the group within the AME department and how sustainability is becoming a key issue in the business.

Drivers for Environmental initiatives at BLC

PE was able to list various initiatives in the BLC group since he had started to work there. For the products, these include: carbon offsetting schemes for cars, start & stop systems, lightweight aluminium body and architecture and hybrid diesel engines. Examples in the process side include investment in a more efficient boiler house, and a performance management system that includes environmental and social criteria based upon the balanced scorecard.

The main driver, in the opinion of the interviewee, is the fact that the company needs to respond to customer demands. BLC needs to deliver a product which the customer wants to buy and society can accept. He emphasised that: “As a business, customer is the prime driver as compliance has always been there. Also, organisations are made by people; and people in BLC want to offer more environmentally-friendly products. There is a desire to produce good product to society”.

Decision making process at BLC

The interviewee highlighted that strategic decisions are obviously made by senior management.

However, there is an environmental facilitator in each area in the improvement committees.

The various committees established were categorised into three levels:

Table 5.3 – Levels of environmental decision at BLC

Level	
1	The meetings are at very senior level, looking at the overall strategy. They usually meet every three months;
2	Senior management meet with representatives of each function, which also meets every three months
3	These are subcommittees or working group that meets monthly in order to implement the strategy. That is where he is involved, representing AEM. These committees have representatives of each key functions: HR, Marketing, Product Development, Site Services, etc.

According to the interviewee, these committees had been running effectively over the previous 12 months and were facilitated by an employee from the Strategic Business Unity, a new department.

There are models and software that help technical decisions within the AME team in looking at a life-cycle approach. However, there is no management structure to take environmental decisions.

PE believes that a model that helps people to communicate and align with the scorecard metrics would be useful. However, it should not take away freedom or be too narrow to avoid impeding innovation culture. In addition, organizational culture in a broader sense should also be respected.

Origin of ideas at BLC

Ideas in BLC emerge from different sources but the majority come from in-house experts and the internal competence in Advanced Manufacturing Technologies. A significant number of ideas are created within departments, through internal environmental survey and reports. In addition, there are partnerships with universities, participation in seminars and conferences, and the use of IT-based knowledge systems.

Green Product and Green Company at BLC

The interviewee understands that a green company needs to deliver product and process in a way that limits its environmental impacts. From an idealist view, a green car could be a car that absorbs CO_2 and emits O_2 from a revolutionary and innovative perspective, says the interviewee.

The BLC case's contribution to theory of green operations

This case supplements the previous case on BLC. It demonstrates how the lack of a strong internal policy can affect various departments by not bringing a clear environmental strategy in place.

Another matter of concern highlighted by this case is how organisational structure can impede or foster the development of ideas and implementation of new solutions. The fact that environmental strategy is not clear from a business perspective may be linked to inter-departmental communication issues as well as over-bureaucratic procedures. Little is understood on the role of the AME department in developing the environmental strategy for the whole company.

Although a metric system based upon the Balanced Scorecard (BSc) methodology is used for performance measurement, the interviewee could not provide enough evidence on how to develop BSc perspectives (financial, customer, process, learning and innovation). Notwithstanding with the relatively long period of ISO 14001 certification (more than 10 years), there is a lack of environmental strategy and decision making structures – which enhances the issues that companies need to go beyond ISO 14001 certification and think strategically about sustainability. For example, how to integrate in the long-term business agenda and decision making processes.

5.7 Case 7: French Automotive Corporation and Waste Management Company (Reverse Logistics)

This case examines warehousing, reverse logistics and environmental decisions. There were two staff members interviewed. They belong to two different companies that work closely in an industrial symbiosis. One is a French Automotive Corporation (FAC) that operates a parts distribution centre in the UK. The second company is a British Waste Management Company that operates in conjunction with the parts distribution centre in a layout that resembles “a plant within a plant” model.

Profile of Interviewees and firms

First interviewee has been working for FAC for about 21 years. He is now Stock Controller in the Parts Division in Coventry, UK. He had previously worked in the engineering, personnel, and finance departments.

In his responsibility (stock management in the Coventry warehouse), the main problems the Stock Controller recalls is the flow of information that allows him to visualise the stocks level. The Stock Controller believes that by improving the information management systems and communication between FAC and the supply factory in France, it would be possible to increase the “visibility” of the parts in the warehouse. FAC in Coventry receives 80% of its items from France. The remaining items come from different local suppliers (those are not necessarily British firms). FAC deals currently with 66,000 references amounting to a total of 180 million individual pieces. Time and motion measures are used to assess the performance of the warehouse. Much of the equipment used in the site (e.g. computers, photocopiers, etc) is leased.

The second interviewee (Waste Manager at the parts distribution centre in Coventry - WM) has been working at the Waste Management Company (WMC) for about four years and has an educational background in logistics. WM has started in the Waste and Recycling Department dealing with destruction and data security. Most of the items were high value products like cameras, CDs, remote controls; but he also was involved with waste from L'Oreal processing shampoos and cosmetics.

WMC has five people working in the FAC site. WMC started dealing with waste from a car manufacturing plant in 2002. However, the car manufacturing plant was shut down in 2006 and as a result, WMC's portfolio was substantially reduced, although it could also take advantage of managing the parts waste when the car plant was demolished. Since then, WMC has managed FAC's wastes from its logistics, warranty services, unsold parts, and the general waste from the site.

Environmental initiatives at FAC's Parts Distribution Centre

FAC is in a process of implementing the ISO 14001 environmental management standards for its Parts Distribution Centre. An activity already in process is the Japanese 5S system. One of the main environmental risks in the operation of the warehouse is handling some of items that contain toxic substances such as anti-freeze oils and fluids, paints, solvents and batteries. These materials, as well as airbags and other high-value items, receive special attention and have separate stock areas. Fortunately, spills of hazardous materials are not a frequent occurrence in the warehouse.

Another problem mentioned by the Stock Manager is the poor management of warehouse space. He indicated that it is almost impossible to predict demand and supply of the items. Moreover, commercial decision imposed by legislation such as recalls, create considerable pressure on the occupation of the warehouse. However, the demands from recalls are predictable and communicated one or two weeks in advance. Nevertheless, these are extraordinary demands and sometimes create problems.

The Stock Manager believes that the central location of Coventry influenced on the decision by FAC in choosing this for the part distribution centre. From the logistics sustainability viewpoint, he regrets that the parts arrive at the Coventry site by lorry rather by train. "In France, there is a rail station and it would be much convenient and greener if we had one here as well", he said. All the parts that are in the warehouse are relate to warranty issues, but also there are some items kept for legal reasons (e.g. end of life batteries). The warehouse is basically divided in two areas: one for smaller parts (i.e. less than 12.5kg in weight and smaller than 600.5mm) and another one for all other items.

At the time of the interview, the warehouse was working today on its full (and sometime over its) capacity however this is not always the case. The interviewee understands that an enterprise resource planning system such as SAP would be useful for material control and forecasting. He admits that FAC may not be responsive enough to attend to some orders, which can have serious customer service implications.

According to the interviewee, the importance of environmental issues has increased dramatically over the years. For instance, he points out that environmental, healthy and safety issues are reaching the forefront of businesses, by not only legal actions, but also through internal initiatives. He affirms:

> "There is much more attention today to reduce parts waste and the use of solvents, for example. Also, we see people's attitudes and perception changing because everyone is speaking about the environment."

Environmental initiatives at WMC

The primary activity of WMC at the FAC site is waste segregation and processing (dismantling, cutting, and balling). Cardboard, wood pallets, metals, and catalytic converters are the main material that WMC receives from the automotive company.

The automotive companies work in what the interviewee considers a perfect symbiosis. "As WMC is the expert in the field of waste management, so they (Auto Company) would listen to us", said the Waste Manager. He continued: "we send to them budget and finance reports. They require us to keep the recycling level higher than 92%. Nowadays, we reached 96 to 97%". The symbiosis implies that WMC can take responsibility for the waste while they can concentrate on its core competences of making cars.

One of the main managerial problems is getting the shop-floor personnel to buy into the "idea" of segregating the waste and avoid wrong disposal. Cost is still a major concern. For instance, windscreens are parts that go as a separately collected faction to a glass recycler (at a cost) because it is too costly to remove the gel layer between the two glass layers at WMC's facilities.

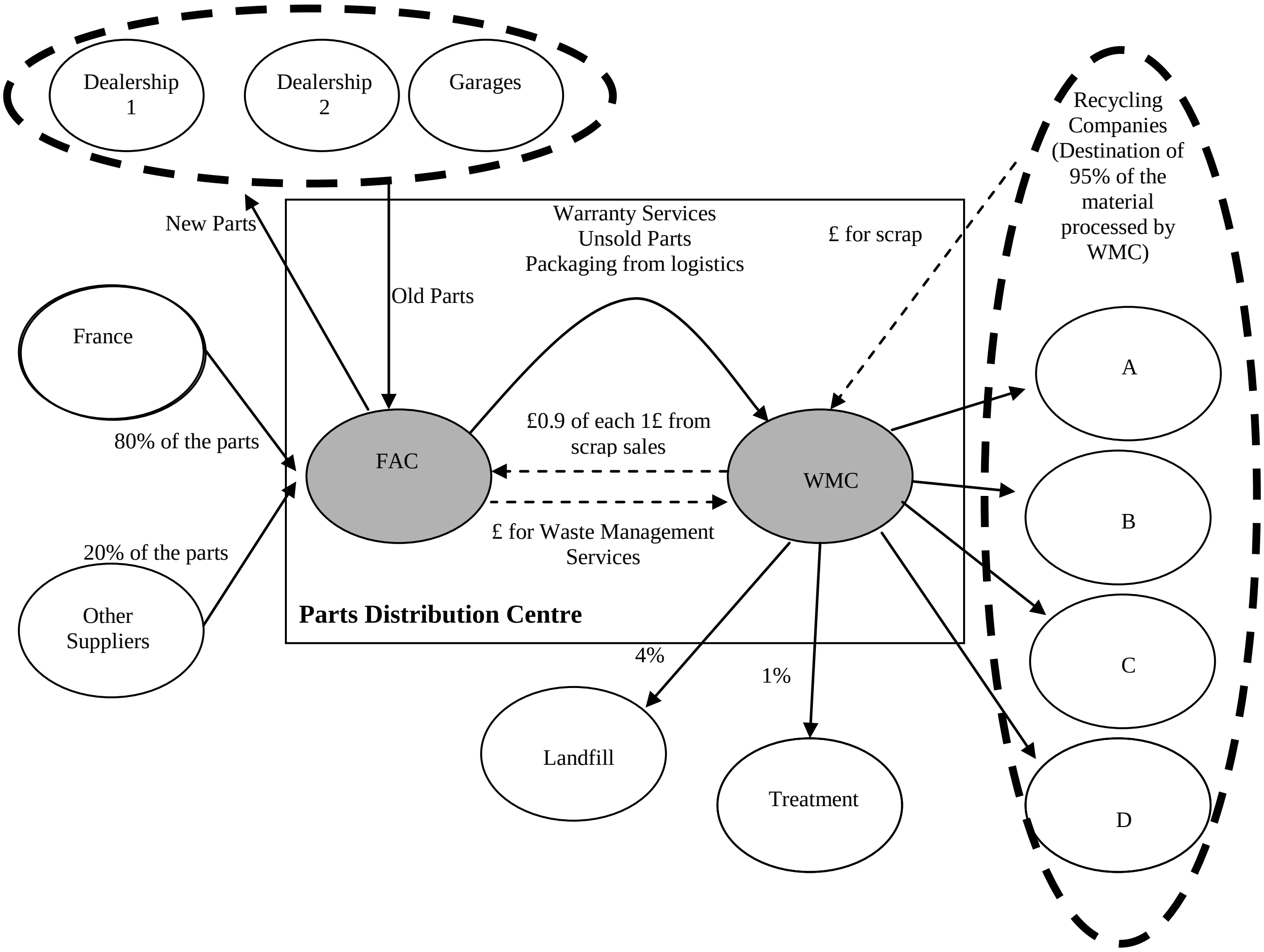

Figure 5.1 –Flow of material and capital in FAC's reverse logistics

Besides, the problem of shop-floor awareness to segregate the waste properly, other major problems for WMC are related to the volume of mixing material they receive from FAC (e.g. packaging mixing plastics and cardboard) and feasible and cost-effective disposal solutions. The interviewee had examined some disposal solutions provided by the National Industrial Symbiosis Programme (NISP), but they are usually cost neutral and sometimes negative.

WMC is paid by the auto company for the service of waste management. It also gets a 10% commission on recycling, which encourages it doing a better segregation and avoiding landfill disposals. The material and cash flows are shown in the figure 5.1.

The FAC and WMC case's contribution to Green Operations Theory

The contribution of this case to theory resides in the path taken by the automotive industry to deal with legislation-driven and costly activities regarding end-of-life of auto parts. The classical question "to make or to buy" is posed here and outsourcing emerges as part of the environmental strategy in order to allow the company to extract value from scrap, avoid environmental liabilities on the final disposal, and reduce costs with landfill. Indeed, the environmental initiatives were preceded by quality management systems and there is a perception that the integration of IT systems would improve environmental performance.

Again, an important issue on international benchmarking appears which favours companies with global production footprints. By operating in different countries, the company is exposed to a wider range of operations management practices that may allow them to seize upon higher environmental gains.

5.8 Chapter Summary

This Chapter explored Green Operations initiatives in seven automotive companies. The primary data collected from these cases will enable the researcher to build a deeper understanding of the drivers, origin of ideas, and environmental decision making processes in the auto industry. The findings presented here are discussed in Chapter 7 in conjunction with the findings from the case study in non-automotive companies, which is presented next in Chapter 6.

After having compiled, organised, and analysed the information from secondary data from the environmental reports (Chapter 4), this Chapter has focused more on the departmental-level environmental decisions as well as their interaction with other departments within the case organisation. The conclusions of this thesis to the automotive industry are the combination from the lessons learnt from the findings and discussions of Chapters 4 and 5.

Chapter 6 – Findings from the case study research in non-automotive organisations

This chapter presents the findings from case study research conducted within non-automobile organisations. Similar to the previous chapter, the unit of analysis considered in this study was the decision making teams, or the decision maker himself (or herself).

All the cases were investigated for decisions at the supply chain level, mainly for strategic decisions. The primary data was collected from personal interviews using semi-structured questionnaires. The findings and conclusions from these cases were used to identify the differences and similarities between environmental decision making processes in automotive and non-automotive industries. Furthermore, findings and conclusions were an important input in the further development of the GRASS model and its validation. As in Chapter 5, it includes the investigation of issues related to drivers, origins of ideas, and structures of environmental decisions; however the focus was mostly related to supply chain management departments.

6.1 Case 8 – UK Carpets (Green Supply Chain)

The purpose of this interview was to evaluate the company's environmental initiatives and decision making at the supply chain level.

Interviewee's profile

The interview took place at the safety and risk management office in the Kidderminster plant of UK Carpets. The interviewee has worked with UK Carpets since leaving school. He was sponsored by UK Carpets during his university education and has been working as the company's Safety and Risk Manager (S&R manager) for five years. His responsibilities were initially related to Group health, safety, insurance and security. Recently environmental issues had also been incorporated into his area of responsibility as these had grown in importance.

Environmental initiatives at UK Carpets

In the autumn of 2007, the executive team of UK Carpets identified the need to address environmental issues in production through a formal environmental management system. The idea was to adopt the ISO 14001 environmental management standards as the way forward.

"For a premium company like we are, we were not as good as we should be. We were doing good stuff, but we had never taken it seriously to put together a plan." (S&R manager)

The main pressure came from the Commercial Director who pushed for ISO 14001 certification. According to S&R Manager, the Commercial Director had started being asked by customers, particularly in the USA, about the company's environmental performance and credentials. They believed that by not having environmental credentials could implicate in losing orders.

All significant sites were certified, namely: manufacturing sites in Portugal, India and the UK, as well as the sales centres in the USA and Australia.

Drivers for environmental initiatives at UK Carpets

The environmental initiatives undertaken by UK Carpets had as a key driver customer requirements (commercial customer in US). "It was customer-driven initiatives to the point where we need to have more information to fill up questionnaires sent by the customers who we wanted to supply carpets", explained the S&R Manager.

"Few years ago, the environment was a marginalised thing (by customers) and it was something that only Greenpeace was worried about and nobody else was really interested. But in the last few years, it has become more and more main-stream."

Top administration established a 12-month target for achieving ISO 14001 certification. Government grants were also very important in Portugal in helping the implementation of environmental initiatives; however, it was not the case for other sites. As the top administration had committed to the cause, the company moral responsibility (internal policy) had also played a role. The S&R Manager explained:

“Morally, we want it too anyway. But it was a question of prioritising it and allocating resources to it. Eventually, the internal Environmental Social Policy – to lead the sector 2015 – becomes a key driver for environmental initiatives too”.

The importance of green issues for the business at UK Carpets

The importance of green issues was triggered by commercial customers. UK Carpets received questionnaires about environmental measures to be responded in 2007, which demonstrate how green issues became commercially important. The S&R Manager explained that the customers wanted a number to represent their greenness. So, UK Carpets discloses the energy, water and waste per square metre of carpet produced. Now, UK Carpets has got to a point where it is providing more information than what the customers wanted.

“We started getting big American hotel chains, primarily, saying: How environmentally-friendly are UK Carpets? How green is UK Carpets compared to nylon carpets?” (S&R Manager)

The importance of environmental issues is mostly addressed in the manufacturing plants however, these are also being considered in construction as UK Carpets is building a manufacturing plant in China under the LEED accreditation. The reason for that was the environmental social policy. The Leed accreditation implicated an extra cost, but the S&R Manager indicated that it was not a difficult decision to make. The construction of the China factory is the first building project after achieving the ISO 14001 certification. “If you want to become a sector leader, there is no way you are going to build a factory in China not bothering about the environment”, claimed the S&R Manager.

The S&R Manager further explained that UK Carpets intends to address both corporate and product carbon footprint in the near future. This will include offices and logistics activities. Also, the new manufacturing plants are close to where the markets are.

Environmental Decision Making at UK Carpets

Environmental decisions are usually easy to be taken at UK Carpets. The S&R Manager believes that these decisions are easy now because they are in the beginning of greening UK Carpets and the path is obvious. He also thinks that it will become less obvious and more difficult as they progress with the task.

Major decisions are always made by the execution team. The decision making process follow two main steps: (1) Preparation (research), and (2) presentation to the Executive team. Consultants are usually employed to provide assistance during the process. Environmental decisions have recently been expanding towards supply chain level which may make it harder and less obvious. New decision criteria will be added shortly, including environmental and social policy, brand image and group values.

As mentioned earlier, green supply chain initiatives are to be encouraged in a near future. At present, UK Carpets is using the ISO 14001 criteria regarding key supplier evaluation. However, there are concerns with company acquisition as little is known about the suppliers of the newly-acquired plant.

The S&R Manager believed that UK Carpets does not need a model or any tool to support environmental decision making today.

Environmental Metrics at UK Carpets

Environmental metrics in UK Carpets include: energy, water, waste, waste recycled, and end-of-life. Energy, due to its high cost, was the first metric to be controlled. However, end-of-life is now gaining attention due to the nature of the premium carpet. Nylon carpets can be recycled into bottles, etc; but woolly carpets mix different materials (to meet the required quality standards) that are difficult to be segregated later in order to go to recycling. Although nylon carpets incorporate a larger proportion of renewable material, the product faces major concerns regarding its final disposal. Having an end-of-life option will be an important part of UK Carpets' environmental performance. The importance of end-of-life as a metric has customer and legislation as the key drivers.

The S&R Manager highlighted that they do not have responsibility over the carpet in the end of its life; however it would be "commercial suicide" to say: "It is not our problem." It is difficult to say that companies could opt for a different business model such as leasing carpets rather than selling them.

A life cycle analysis is in course to understand better the environmental performance of the carpet throughout its whole life: raw material extraction, transportation, manufacturing, maintenance, and final disposal.

Designing a green product and defining a green company in the perception of UK Carpets

The S&R Manager explained the existing tradeoffs to produce an environmentally-friendly carpet. First, he highlighted the fact that premium carpets need to be of a higher quality due to their use in high-traffic places like hotels, casinos, cruises, etc. With the existing technology, a green carpet may not do the job the customers want it to do. On the other hand, the longevity of a high-quality carpet is part of its environmental performance.

The S&R Manager further said that to be a green company, it would need to supply a green product. In that case, a green carpet could be a carpet that lasts forever; completely recyclable, with little environmental impact in cleaning it and fitting it and easy and energy efficient to recycle. Given the costs, the green carpet needs to appear as of exceptional quality from the day it is installed. A green company also needs to be efficient in manufacturing, logistics and R&D.

Where do ideas come from at UK Carpets?

UK Carpets uses different sources of ideas for environmental initiatives. The safety and risk management department is itself an important place where ideas come from. Portuguese consultants play an important role in suggesting environmental improvement in the manufacturing sites of the UK Carpets. University researchers from Leeds are also involved in the process of generating new ideas as they investigate the corporate carbon footprint. Last but not least, employees also participate in bringing their own suggestions on improving the group environmental performance.

The UK Carpets Case's contribution to the theory of Green Operations

This company serves as an example where the company receives external pressure to become greener and the internal policy makers understand that pressure from a strategic perspective. The assumption here is the fact that the company had other organisational competences (e.g. safety and risk management) which could support the development and implementation of a green operations strategy.

UK Carpets had as the key driver for greening operations customer requirements. Although a number of initiatives on environmental issues were being pursued, the lack of a formal structure did put the company at risk of losing sales orders. However, when the top administration decided to provide support, the company quick implemented ISO 14001 and obtained certification for all significant production sites. Also, being taken as a strategic issue, UK Carpet looked for financial support from government. The evidence to the strategic perspective taken from UK Carpets is the quick migration towards broader types of certification in new manufacturing plants (LEED certification in China). Although the standards were far above the local legislation, UK Carpets understood that going to China could create doubts about the company's environmental credentials and as a result, it opted for an American certification that customers would appreciate.

Another important issue raised from this case is the conflict to match green product with business strategy. While it is easy to justify the greening of manufacturing and facilities, the greening of the product is full of complexity, subjectivity, uncertainty, and business risk. There are technological, economical, and quality requirements that may not be met under the current view of what a green carpet is.

6.2 Case 9- Thai Garments (Green Supply Chain)

The purpose of this case was to evaluate the company's environmental initiatives and decision making at the supply chain level when operating in a developing country. The CEO of Thai Garments was interviewed for two hours. The company produce a large variety of garments (apparel fabric for men, women and children) and has Nike as one of its customers.

Participant profile and Environmental Policy

The interviewee was the Managing Director (MD) and partner at Thai Garments. She has been working in the company since 1984 and her responsibilities include participating in the managerial decisions for the whole company besides taking direct responsibility for the sales department.

The company is certified to ISO 9000 the quality management standard; however, it does not have ISO 14001 certification yet. No environmental policy was established yet, apart from meeting the legislation requirement. The MD of the company highlights the difficulties Thai Garments faces in order to receive its ISO 14001 certification. A consultant was hired to assess the company's readiness to implement an ISO environmental management system; but due to location issues, the companies decided to postpone its implementation. The current location faces problems because it is below sea level and floods from underground water occur frequently. This can compromise the implementation of environmental programmes as well as the fact of increasing the cost. Due to this problem, the company is thinking about building a new production facility in another area and then proceed to achieving ISO 14001 certification for that site.

Thai Garments does not have an Environmental Manager in place. The company accommodates environmental issues in the managerial structure with a working group, which discusses and brings ideas to improve the company's environmental performance – mostly related to energy saving initiatives. The working group has been operating for two years and has 15 people involved.

Environmental initiatives and origin of ideas at Thai Garments

There are two main streams for environmental improvement in Thai Garments: (1) Energy saving; (2) air pollution control. Energy saving initiatives vary from small issues such as lighting (switching to compact energy saver light bulbs) to large elements of production such as the choice of machinery. Both initiatives are driven by cost reduction and improvements in workers' conditions. An example of this is the new air conditioning system that has an evaporator, which allowed the company to reduce energy consumption as well as the costs and dust in the working environment. Cost of electricity was cited as one of the main reasons to pursue energy savings in Thai Garments.

Most of ideas are generated in house. The working group meets regularly to discuss ways to save energy. External sources are used for more technical issues. As the company is a member of the Federation of Thai Industry (FTI), it receives advice from FTI consultants on how to improve their production process. Other consultants are also hired to help with machinery choice.

As mentioned earlier, Thai Garments' future plans include building a new production facility in a different location in Thailand, which would contemplate an environmental management system certified by ISO 14001 standards. The main reason for seeking ISO certification is corporate image. Although Thai Garments has major companies such as Nike as clients – there is no pressure from the customer base for ISO 14001 certification.

Decision making process at Thai Garments

Environmental decision making in the company is divided into two groups: large and small projects. Large projects, such as the 10-million Bahts water treatment station, needs to go through the scrutiny of top administration for viability analysis. Small projects which can be ideas from employees and the working group are only presented to the MD, who evaluates the benefits from the investment, and finally, approves or rejects its implementation.

The criteria used to assess the environmental projects in Thai Garments are: (1) Worker condition, (2) Amount of the Investment, and (3) Return on investment (ROI) – in this priority order, according to the interviewee (the MD). For instance, the approved project for a new air conditioning system had a payback time of one year.

The MD admits the company needs help to take environmental decisions. For her, Thai Garments need technical assistance mainly related to its machinery investments.

Green Supply Chain Initiatives at Thai Garments

Main environmental issues at the supply chain level are internal. Purchasing activities are only affected in the case of customers' special requirements like the use of chemicals in the colour formation and standards. Few issues were found related to greener transportation initiatives. A plan for substitution of petrol for natural gas did not happen because it did not meet the ROI criterion for the company.

Environmental initiatives regarding the internal operations (besides the energy saving and air pollution previously mentioned) include waste management for saleable by-products such as fabric, plastic and paper. All those are stock and sent to recycling facilities in batches regularly.

Thai Garments has no environmental criteria to select suppliers but respond to legislation compliance. Inbound logistics is the responsibility of the suppliers, while the company owns 12 trucks for out-bound logistics for domestic customers. For international customers, a third part logistics is used.

According to the interviewee, the environmental pressure on Thai Garments is low because it is not in the down-stream end of the supply chain. Another issue related to pressure refers to the performance of competitors: "In this industry, no one wants to get ISO 14001", said the MD. As the company shares the same suppliers with the main competitors, there is not much pressure passed on to the up-stream either. However, if a customer like Nike requires an evaluation or auditing on one of Thai Garments' supplier, it will check its workers' conditions and performance.

Environmental Performance Measurement at Thai Garments

Due to the lack of an established environmental management system, the company does not have an environmental report to disclose its environmental performance. Environmental performance is only understood as meeting local law requirements and work conditions such as noise pollution control. Energy consumption is measured as part of production management; and there is no individual environmental performance measure for products.

The Thai Garments Case's contribution to the theory of Green Operations

This case illustrates the environmental decision making in a reactive company. It is clear how the lack of external pressure and poor internal policy can lead to inaction towards higher environmental performance, and especially, to the development of an environmental strategy.

The Thai Garment's mangers cannot visualise the value of environmental initiatives beyond financial payback. Therefore, they react to pressures from customers and benchmark themselves against local competitors. Since the company does not receive any pressure from its suppliers and local competitors have similar behaviour, the company has only efforts to meet legislation requirements. This behaviour inhibits the company to investigate and pursue initiatives that would enhance its competitive advantage, and of course, are appropriate to the nature of its business, size, and context where it operates.

6.3 Case 10 - Thailand King's Sea Food (TKS)

Thailand King's Sea Food is a manufacturer of frozen sea food. The company processes sea food in its production facilities in the surroundings of Bangkok. The purpose of this interview was to evaluate the company's environmental initiatives and decision making at supply chain level. The Managing Director Assistant (MDA) was interviewed for two hours and guided a one hour plant tour with other staff members.

Participant profile and Environmental Policy

The interviewee has been working for TKS since October 1992. She had previously worked in the Marketing area and at the time of the interview held the position of Managing Director Assistant. The Managing Director is the owner of the company.

In 2005, the company obtained certification for each of its five production plants with ISO 14001 environmental management (EMS) standards. TKS has an Energy & Safety Manager who takes responsibility for the EMS. A copy of the Environmental Policy was provided in a hard copy and is also available online. It states that:

> *"The company is committed to produce and develop the quality of product in which stringent hygiene and quality control with no effect to the environment under the International Standardization continually to serve the needs of our valued customer"*

Major issues in the environmental management system are: energy, water and air pollution. Because of the nature of the food processing industry, which is under strong safety and hygiene controls, the drivers for certification also include federal and local government legislation (e.g. Ministry of Industry, Ministry of Public Health, etc), customers' standards, and special requirements.

Environmental initiatives and origin of ideas at TKS

The main environmental initiatives are related to the implementation of ISO 14001 EMS. These initiatives are always taken in conjunction with labour conditions concerns as part of the improvement programmes of the environmental management system. As a result, a number of programmes were established to reduce energy consumption, especially in areas such as the power grills, which is energy intensive and requires use of air conditioner control the work environment at a reasonable temperature. Other initiatives aimed at reducing energy consumption include change of light bulbs, new ways of cooling air for the grill area.

Environmental concerns have gained importance in the last few years mainly due to volume increase and introduction of new items in the production line. For instance, water treatment has also been an area of investment for the company. The manufacturing processes are water-intensive and due to volume increase and added substances in some products, water treatment has become more difficult and expensive, requiring supplementary investment.

"This factory is nearly 18 years old. In the beginning, we had only one factory; but now, we have five factories in this area – the water treatment is not enough… we need to make it bigger", said the interviewee.

Environmental initiatives were triggered by change in the international business. Customers started requiring information about environmental performance and certification. The interviewee explained:

“This is due to international business. In the beginning maybe, every country was concerned about cost, tariffs, barriers, quality, and the conditions of the workers. I think World is changing to many non-tariff barriers. We need to have the international standards. After we had ISO 9000, we have to go to the next step – and have ISO 14000”.

Along with the changes in international business, the company named the following drivers for taking environmental initiatives: electricity costs, legal issues in water treatment, customers’ requirements, local and federal legislation, local and international competitors, and social responsibility (brand image).

Ideas for the environmental initiatives come from different sources. Customer suppliers, auditors, and governments contribute sometimes as part of the company’s environmental learning. Experts are usually hired for special projects. Internally, all departments report their performance and bring their suggestion for better environmental performance.

Environmental decision making process at TKS

Environmental decision making in the company seeks consensual decisions across departments; although the final decision is made by the MD. Decision making process includes cost-benefit analysis and an evaluation of what would happen if the company does not take or implement the decision. Decision criteria considered in the company meetings are: cost, benefits, image of the company, and the risk of not doing anything.

Environmental decisions vary in their levels of difficulty. While some are easy and straight-forward; other are very difficult. The interviewee reckons that access to technical information could help the company in some situations; mainly, to confirm that the information from the Energy & Safety department is reliable.

Green Supply Chain Initiatives at TKS

TKS currently has more than 200 suppliers. Regarding the green supply chain initiatives, the company has environmental, safety and sanitary requirements for its suppliers. Supplier management includes supplier selection and evaluation. Evaluation is done by yearly audits to determine the supplier performance. TKS's personnel visit some of its suppliers in order to monitor quality practices.

Many of TKS's requirements are in fact requirements from its customers. These include issues with packaging (PVC-free and recycled material). For instance, Japanese customers required reduced packaging because of the high taxes they need to pay for final disposal of the product and cost for material separation. These requirements have also implicated in including more information in the product label. Further initiatives such as purchasing from organic producers are considered difficult. On the other hand, internal initiatives for non-production areas are undertaken. These include avoiding printing, energy conservation, use of recycled paper, etc in office facilities. As part of the ISO 14001 EMS, environmental impact assessments are used to serve as a guide for environmental initiatives. The greening of logistics is provided by better scheduling; however, the company is not responsible for inbound or outbound logistics. Nevertheless, there is a concern with the condition of the vehicles as they transport perishable products. Due to these legal, sanitary, and quality issues, the fleet of these companies tend to be in very good condition.

As all logistics is outsourced, outbound logistics is the part which the company concentrates its efforts on in its evaluation. A check-list exists that needs to be followed for every delivery truck to assure quality. The selection and management of third part logistics also includes environmental criteria.

Environmental performance measurement at TKS

Most of the performance measurement is process-based. Due to the high product variety, there is no individual product performance analysis as it is too complex and difficult. Further information is provided in the environmental report.

The TKS Case's contribution to the theory of Green Operations

This case company provides an example of how the nature of the business and the sector wherein the company operates can trigger a higher environmental awareness and help to develop a strategic view of environmental issues.

TKS identified long-term issues that impact the company's environmental performance such as production increase, product mix, and the age of machinery. Being engaged in international business and associated with the tough legislation in the food sector has pushed the company to develop long-term environmental initiatives.

Although operating in the same country as Thai Garment's, the hygiene and safety legislation has forced the company to strengthen its internal policy towards long-term issues that may put their business in jeopardy. The company's relationship with its customers is another important issue which shows how governance in supply chains can support environmental initiatives and contribute to a stronger environmental internal policy.

The TKS case study demonstrates also similarities with other cases by evaluating the implication of not going green (as JMC and UK carpets did) and greening operations through outsourcing (similarly to FAC).

6.4 Case 11: Chemical Company of Thailand (CCT)

In a 4-hour interview with the two top administrators, the purpose of this interview was to evaluate the company's environmental initiatives and decision making at supply chain level. Chemical Company of Thailand is an export manufacturer of synthetic leather and synthetic resin in Thailand.

Participant profile and Environmental Policy

The interviewees were the Managing Director (MD) and the General Manager Assistant (GMA) of the Chemical Company of Thailand (CCT). Both interviewees had been with the company since 1978 and consider themselves as part of the family that owns a Chemical Industrial group, of which CCT is a part.

At the time of the interview, CCT had been certified to ISO 14001 for three years. The environmental issues are under the responsibility of the Energy and Safety Department. Also, every department in the company has a representative who participates in the environmental committee. CCT's environmental policy is included in the environmental report

Environmental initiatives and origin of ideas at CCT

The interviewees highlighted the importance of regulations in the chemical sector. Because it is a strongly-regulated sector, meeting the environmental legislation requirements is already a daunting task, but one that guarantees a satisfactory environmental performance. Also, companies that meet the environmental legislation tend to have high respect from their customers who continue to do business with them.

CCT has been investing in a number of different environmental initiatives: (1) water treatment, (2) energy use, (3) re-use of chemical residues (waste), and (4) air pollution control. For instance, in the energy use and air pollution control initiatives, CCT has substituted heavy oil as the main fuel with light oil, which is more efficient and has lower costs and emissions. Due to the high oil prices, there was a plan to start using biomass in a self-sufficient power plant; however, as the oil prices went down again, the project was cancelled.

Waste management has two main components: (i) recovery and reuse of chemical in the process, and (ii) appropriate treatment and final disposal of waste. Air pollution is controlled due to the strong smell of emissions, which although is not toxic, it creates problems for the communities in the company's surroundings.

The main drivers for environmental initiatives are the company's environmental awareness, cost reduction, corporate image, and legislation compliance. Although in its beginning CCT faced the trade-offs of profitability and a higher environmental performance as it was a crucial moment for survival, environmental issues have been in the business stream for a long time.

Most of ideas implemented come from the company owners and the environment committee. For special projects like the biomass power plant, CCT uses external consultants.

Environmental decision making process at CCT

Environmental decision making and policy in the company divides projects according to its size. Large projects are evaluated by the top administration and a project manager will need to take responsibility in studying the initiative pros and cons to help the team in taking decisions. Small projects have a less structured approach – they are evaluated by the environmental committee, appraised by the MD and taken forward by the departments.

Decision making process considers the investment amount and ROI, pros and cons assessment, corporate social responsibility culture, and image. An example of initiative that highly weighted image rather investments, cost or legislation is the elimination of smell from the factory's emissions.

Decisions tend to vary in the level of difficulty. If it is a decisions associated with the core part of the business, which decision makers are familiar with, they say they can handle it well. On the other hand, if it is a new area, decision makers may need technical help. CCT decision makers also visit other companies that have a similar process to know more about a possible solution and analyse its results. There is also cooperation with universities evaluating technical solutions.

There is not a structured process in place to take environmental decisions in the company; mainly when it is an internal discussion. Nevertheless, consultants have been using decision making tools to help CCT in its environmental decisions. As the company does not own these tools, there is not much detail available about them. As a rule, decisions are taken in meetings and through discussions where experience plays an important role.

Green Supply Chain Initiatives at CCT

As mentioned before, CCT's business is strongly regulated by the government including the environmental agencies. The strong regulation also affects the up-stream supply chain. In the chemical sector, the entry barriers are high which results in a small number of large supplier companies. The main environmental criterion to select suppliers is legislation compliance – because of the strict legislation, by meeting the legislation standards, it means that the company becomes an eligible supplier to CCT. However, purchasing criteria is supplemented with other criteria (in this priority order), namely: quality, price, delivery, and "problem solving" competences, i.e., the supplier's response to promptly solve eventual problems.

The small number of suppliers makes supply chain management easier – for instance, quality from Japanese and Korean suppliers do not vary much from one delivery to another. On the other hand, some Chinese suppliers are still unable to keep the quality standards for all deliveries. Quality and environmental issues are somewhat entailed in this sector, therefore, as a requirement of ISO 9000 quality systems, the company audits suppliers every six months.

While inbound logistics is under supplier responsibility; outbound logistics is part of CCT's operations. Every inbound delivery is assessed with the company's check list. For outbound logistics, the company needs to meet some special requirements such as drivers' training to cope with accidents. Outbound logistics does not include distribution or sales centres, it only deliveries directly to CCT's customers. There is no packaging involved other than the transportation drums. CCT's responsibility over the product finishes with the delivery unless there are quality issues to be resolved, which could mean the company will recall the product, re-treat and perform another delivery. Quality issues may also include damage to the drums, which does not necessarily affect the product quality.

CCT operates with a zero accident target, which they have already been pursuing before ISO 14001 certification.

Waste management is another major issue in the company. Recycling of chemical waste is regulated by government, which requires CCT to list the composition of its waste and send it only to authorised recyclers. Partially, waste from its process still have value and can be commercialised; if not it goes to appropriate legal disposal.

Environmental performance measurement at CCT

Most of the environmental performance checks towards up-stream supply chain refer to logistics as regulation is enough for their processes in the company's view. Environmental performance measurement in CCT's is process-oriented. Environmental performance measures are available in the company's environmental report.

The CCT Case's contribution to the Theory of Green Operations

The case of CCT reinforces the issues found for companies operating in highly-regulated sectors. Similar to TKS, this case shows how the strong governmental regulations related to safety issues against product specification and production processes can impact on environmental strategies of companies.

CCT senior managers are used to dealing with strong regulations that have direct impact on the company's environmental performance. Therefore, the company had to have a strategic view of environmental issues at the early stages, mainly, with regard to what to do beyond legislation. It was possible to notice how CCT engaged in finding solutions that met the requirements of strategic position, profitability, emissions reductions, and risk minimisation simultaneously.

Also, there is evidence of an environmental awareness maturity that allows the company to visualise risks and benefits of environmental initiatives as well as the implication of choosing not to implement them even when they may not constitute a win-win solution.

6.5 Chapter Summary

Chapter 6 provided an exploration of the Green Operations Initiatives and their decision making process in non-automotive organisations. The findings from these cases are instrumental to compare how companies in different sectors and in the different stages of implementations of Green Operations Practices (GOPs) as well as submitted to different regulative context behave in order to become greener. In addition, the findings from the non-automotive cases will help in understanding the environmental drivers amongst issues beyond the auto industry, allowing the achievement of more robust results from a generalisability perspective.

A comparative analysis between the findings presented in Chapters 5 and 6 is carried out Chapter 7. The fact that the sample of automotive and non-automotive companies is dispersed in different countries at different stages of their economic development has also been a strength to advance on the theory of Green Operations and the conclusions of this thesis.

Chapter 7 - Discussions from the Case Study Research

7.1 Introduction

This chapter summarises the case analyses and discusses the findings presented in chapters 4, 5 and 6. The discussion is centred on the drivers and sources of ideas for environmental decision making. It also includes an analysis of the processes of environmental decision making in the case companies and a comparison between auto and non-auto companies' environmental decision making structures.

Eventually, this chapter reflects on how the data provided insights on the relationship and characteristics of environmental decision making against the operations activities, the use of green operations practices (based on the framework categorisation) in the environmental strategy, and the companies' technical competence level.

The chapter concludes with a summary of the findings and discussion and recommendations for greening global operations supply chains

7.2 Drivers for environmental initiatives

From the interviews and focus groups, it was possible to better understand the main drivers that push companies to pursue environmental initiatives. Legislation, internal policy, and customers were pointed out as the primary motivation to go green and therefore they were considered primary drivers. Without being as strong as the primary drivers and being seen more as a result of environmental initiatives rather than a cause, this study classified environmental performance improvement, corporate image and environmental competitive advantage as secondary drivers

Primary drivers: Legislation, Internal Policy, and Customers

Legislation, Internal Policy, and customers are the main reasons to go green; however, they may act independently or not as the main driver for an environmental initiative. For example, if a new environmental legislation emerges, customers could start requiring environmental improvements that shows that the company will be able to meet legislation requirements within reasonable cost. The same connection with other drivers is also true for internal policy, which may foresee opportunities and risks associated with customers' desires or new regulatory demands, hence, it provides support and requires environmental initiatives to be implemented.

Environmental Legislation

Environmental Legislation continues to be an important driver, if not the most important driver for companies to implement environmental initiatives. Most of the companies cited it as key factor to adopt initiatives. When an environmental initiative is considered to enhance environmental performance and competitiveness, it is still linked to environmental legislation as it may allow the company to stay ahead of it. Legislation in a broader context beyond those from environmental agencies, and seems also to have an impact on companies' environmental awareness and attitude. Highly-regulated sectors may tend to push companies to accommodate environmental issues in their business agenda and strengthen their environmental internal policy. For instance, safety and hygiene legislation may overlap considerably with environmental issues, which lead to a higher level of environmental awareness.

Legislation, as a driver, may impact on both company products and processes. A recent environmental regulation for car tailpipe emissions in the UK will force automobile manufacturers to work on product design, although there is very little understanding on how the customer will accept these product interventions. At the product level, the uncertainty and complexity may lead to conflicting goals on a greener product design, if a robust decision making process is not used. Issues related to customer satisfaction, safety, aesthetics, cost, and environmental performance may be impacted differently when trying to green a product. In addition, when a life-cycle approach is taken, even more complexity results as the company does not have control over several of the activities. For example, the efficiency gains on the engine fuel consumption may be offset by its impact on drivers' behaviour. Since the car is more efficient, it is also cheaper to run, which contributes to a more intensive use of the vehicle. For products that have less elastic demand, efficiency gains have a higher chance of contributing to higher overall gains on emissions reductions.

Legislation indeed varies considerably according to the industry sector and this variation has strong impact on the other drivers such as customers and internal policy. Chemical and food processing companies, which are strongly affected by stricter legislations, are good examples of that. In the chemical sector, companies are satisfied if their suppliers can meet the regulations only. Likewise, customers tend to be satisfied if a company has a good record in meeting legislation requirements and a good history in avoiding fines for environmental accidents. The sea food case company (TKS) controls carefully the safety and health issues in its production processes, merging these issues to environmental concerns in the corporate environmental policy. These safety and health standards are critical to do international business and they become TKS's concerns in managing their supply chain. However, different from the chemical company, the pressures beyond legislation from the customer for higher environmental performance are now being passed onward to TKS's suppliers. The fact that quality, safety, and environmental issues converges well for process-based initiatives in this sectors, facilitate the assimilation of these new environmental pressures.

In a more complex context, companies in the automotive sector look for actions beyond legislation in product development and production processes. Car manufacturing companies tend to require ISO 14001 from main suppliers and develop actions in their supply chain (both internal and external) that are not required by legislation. Notwithstanding with these actions and because of its size and extension, the auto industry is still legislation-driven in several areas of operations function. In terms of product development, the improvement of internal combustion engines is mostly driven by legislation. Recycling initiatives for end-of-life vehicles are similar in most countries, specially due to the fact the infrastructure is needed to make recycling both environmentally-friendly and economic viable.

Internal Policy

Internal Policy is said to be one of the main drivers of automotive companies to take departmental-level decisions. Where internal policy is strong, environmental initiatives for manufacturing seem to be better developed – they are better justified, linked to business strategy, and easy to assess the success rate. Internal policy also fosters group benchmarks, which is an important mechanism to compare brands' performance, transfer of best practices, and reduction of possible risks involved in the implementation of environmental practices.

Nevertheless, the understanding of environmental policy is not always clear. Environmental internal policies are usually broad in nature and based upon ISO 14004 guidelines, namely: (a) legislation compliance, (b) continuous improvement, and (c) pollution prevention. It was possible to conclude that for areas such as product development and supply chain management, it was harder to translate policy into strategic actions.

Generally, there is a poor understanding of environmental strategy and its link to environmental policy. Similarly, environmental policy and strategy are not well placed in the business context, poorly translated into product and operations strategy. These issues can eventually impact on tactical and operational actions towards a higher environmental performance.

By studying non-automotive sectors, this research was able to investigate environmental decision making at the corporate level. Within the automotive cases, most of the investigation was carried out at the department level, where internal policy was considered a primary driver. However, at the corporate level internal policy may work as a mediator, i.e. a variable that affects the direction or strength in a relationship between independent and dependent variables. In this case, internal policy is affected indeed by customers and legislation and can influence eventually on how the company will transform legislation demands, customer requirements, market opportunities, competitors' actions, amongst drivers into implementation of environmental practices, and finally, environmental performance improvement.

Customers

Customers are usually mentioned as important drivers for pressurising companies in the implementation of environmental practices. In this research, however, it was identified that customers are only a very strong source of pressure when they are large and with strong bargaining power. Commercial customers tend to have an effect on the implementation of environmental initiatives, while individual customers usually turn the greening of a product a very complex task. Also, the issues related to product functionality can be a source of pressure to adopt or impede a greener design as mentioned before. The main lesson here is that companies will perceive the pressure of one commercial customer being heavier than the pressure from several individual and smaller customers. It seems rather obvious but very little of that is translated into public policy and corporate environmental strategy.

The relationship between customers and the company seems to be the major factor that determines whether companies will become greener or not. The case companies expressed concerns that individual customers are not very keen to paying more for their own environmental requirements or any extra for a greener product. Changes in customers' behaviour due to product interventions as well are not easy to predict. As a consequence, the environmental decisions are more process-oriented, avoiding changes that may put the perception of quality, aesthetics, and performance of the product in jeopardy.

Secondary drivers: Environmental Performance, Environmental Competitive advantage, and Corporate Image

Classifying drivers as secondary for environmental initiatives may sound as diminishing of their value at the first moment. Nonetheless, the secondary drivers are very important in environmental decision making as they represent a more holistic view of the impact of environmental initiatives. A company that can identify secondary reasons to go green is widening their ‘radar’ to other possible opportunities and risks, or have a different motivation besides legislation, internal policy, and customers.

The relationship between secondary drivers is also one to be investigated further. In some of the cases examined, it was possible to see a lack of justification between environmental performance and corporate image as well as difficulties in determining whether a company was greener than its competitors. These issues were sometimes embedded in the modern complexity of business where it is even difficult to provide a clear picture of who are the competitors, what are the benchmark criteria, etc.

Environmental Performance

Ten (out of the eleven in the sample) companies have demonstrated a good understanding of the impact of a better environmental performance on financial performance. Profitability, potential cost reduction, and return on investment are seen as criteria to select environmental projects, therefore, increasing the image and perception that environmental initiatives are actually a way to build a competitive advantage. Nevertheless, these were more economical rather than ecological motivations for implementing environmental initiatives.

UK Carpets (Case 8) has revealed that they look for government grants in order to fund environmental improvements. Thus, there is an interest for improving environmental performance if public funds are available. In fact, given the manufacturing performance improvement (as a result of environmental initiatives) and the economic motivation behind it, these (environmental) improvements could possibly be implemented even if there was no environmental pressure for them. They could occur under the umbrella of process improvement – part of production plant management in a business-as-usual approach.

Ethical issues and the corporate image

Ten companies have considered environmental initiatives as a way to keep their reputation in business as well as a path to achieve improved corporate image. But for only three of them image was justified as a primary driver (i.e. in a way that they had evidence of initiatives linked to image rather than other factors). Alongside the corporate image, ethical issues, particularly those regarding workers' conditions are mentioned. This is an interesting aspect of the greening of organisations because it emerges from companies in their early stages of sustainability awareness and corporate social responsibility concerns. The garment company (case 9), for instance, belongs to a sector well exposed in the media due to the use of sweatshops and child labour. Hence, there is a major concern to tackle these issues at its earliest moment as part of the sustainability initiatives. Thereafter, companies include more environmentally-friendly features to their image, and these include projects without paybacks, educational and philanthropic initiatives, as well as project not necessarily in the business stream of the company.

Although still controversial in the scientific and popular circles, case companies name global warming as a driver for environmental initiatives. They want to show that their organizations are doing something to avoid global warming.

Local community is also a driver very much connected to corporate image and ethical operations. The work of JMC (case 1) with global warming awareness and educational programmes, as well as the CCT's (case 11) work in avoiding unpleasant smells (although within legislation permissions) is evidence of that. BLC (case 5) cites the carbon offsetting initiative as an evidence of trying to improve their image.

Although the data show that legislation compliance, with possible cost reduction, continue to be the main final objectives behind environmental initiatives, companies' interviewees say that the environment is getting more and more important in the business agenda and their initiatives are starting to become broader than the legislation, therefore, becoming part of companies' internal policies. Thai Garments (case 9), with weaker environmental legislation and less pressure from commercial customers, demonstrated fewer initiatives within and beyond manufacturing. On the other hand, the pressures from commercial customers have a stronger weight than legislation in Premium carpets case (case 8). Despite being complete asymmetrical, both cases mention their concerns with environmental reputation. As the environmental rankings are starting to be established and publicised, customers may pay more attention and environmental competition could be triggered.

Most of the environmental initiatives were customer-driven, because without environmental certification both the image of the company or the commercial relationship could be in jeopardy. In the automotive industry, because individual customers are numerous and perhaps more important for most market segments than commercial customers, their actions are more driven by legislation with regards to product development.

Environmental competition

Environmental initiatives are seen mostly from their impact on environmental performance and return on investment perspectives; only three companies in the sample related environmental initiatives as part of the corporate strategy or important for the overall business. Other seven mentioned 'environmental competition' by looking at competitors' actions and benchmarking but not in a strategic analysis.

Another important factor revealed from the case analyses is that environmental competition is still low and in its early stages regardless the sector or location. Hence, the level of ecological innovation and competition to take the environmental leadership is not evident, and mostly related to brand image. Only the JMC (Case 1), UK Carpets (Case 8), and TKS (Case 10) were the companies that explicitly demonstrated concerns in being ahead of competitors in environmental performance.

The implications of low environmental competition are of serious concern. Without the competition 'mental model', companies struggle to understand how they are positioned against their direct competitors. Although there were improvements lately with the emergence of industry-related rankings such as the 'Guide to Greener Electronics' by GreenPeace International and the generic classification of sustainability index by Dow Jones, there is a clear lack of an instrument or methodology that assesses how environmentally-friendly products and companies are in relation to their main competitors. As a result, companies have little clue on where to be and what to do in the environmental race.

Table 7.1 summarises the use of drivers in the justification when implementing environmental initiatives for each case.

Table 7.1 Analysis of drivers for environmental initiatives

Companies	Legislation	Customer Requirements	Internal Policy	Environmental Performance	Environmental Competition	Corporate Image
Auto Group of Deutschland	++	0	++	++	+	+
German Premium Cars	++	+	+	+	+	+
Waltham Luxury Cars	++	0	++	++	+	+
BLC (Product Development)	++	+	++	+	+	++
BLC (Manufacturing)	++	+	++	0	0	+
Japan Motor Corporation	++	++	++	+	++	++
Parts distributions	++	0	++	+	0	0
Thailand King's Sea food	++	++	+	++	++	+
Thai Garments	++	++	0	+	0	+
Chemical Company of Thailand	++	++	+	++	0	++
UK Premium Carpets	+	++	++	+	++	+
Total scores						
++	10	5	7	4	3	3
+	1	3	3	6	4	7
0	0	3	1	1	4	1

Legend

++ Strongly advocated in the justification as primary drivers

\+ Mentioned in the justification as a consequential benefit or as secondary driver

0 Not considered nor valued as a driver for environmental initiatives

7.3 Origins of ideas for environmental initiatives

According to the collected data, companies have a variety of sources to generate ideas for environmental initiatives. These include their own personnel at all organization levels, industry experts, consultant, customers, suppliers, industry federations, group database and standards, and suppliers.

A closer analysis shows that technical issues and large projects usually receive external help (consultants and industry experts). In-house experts also contribute for technical decisions; while top administration always participates in major project decisions. We could also notice that customers play a minor role in suggesting environmental ideas, and middle management and shop-floor associates have a strong role in finding solutions for continuous improvement.

In the case 4 (AGD), which operates in the USA, the Environmental Protection Agency has played a major role in fostering the large environmental initiative of a landfill gas project. This shows how governmental and regulative agencies can work in conjunction with companies beyond auditing for legislations breaches and applying fines.

Differently from manufacturing activities, product development (PD) ideas are dealt mostly internally, by the PD teams due to issues of confidentiality. In Waltham (Case 2), PD teams do not even share ideas with manufacturing teams to avoid intellectual property theft. In addition, this fact does indeed receive the influence of suppliers and top administration; however, as Hoek (2002) mentioned, it is not very well integrated with other areas and the overall business environmental strategy.

The limited participation of university and research centres as origins of ideas is worrying. There might be a gap on what researchers are investigating or a lack of communication between industries and universities in order to connect the increasing demands for green ideas and its generation, assessment, and documentation, which are primary roles of universities. Only two out of the 11 cases have explicitly mentioned collaboration with universities.

7.4 Process of decision making

The processes of environmental decision making in the company cases have major similarities. First, they tend to follow similar paths and criteria of other business decisions. Environmental issues are usually seen as a threshold to be achieved, a qualifier rather than an order-winner criterion in most decisions. However, once they are seen as important strategically, for the overall business, they may emerge as the main business criterion. For instance, Waltham (case 2) changed the business criteria for viability of environmental projects. Instead of the usual 2-year period to pay off; they extended the pay off period to 5 year when evaluating and approving environmental initiatives. Image is also considered an important criterion. The CCT (case 11) company, for example, weighted image the most important criterion rather than investments, cost or legislation when eliminating a strong smell from the factory's emissions that was affecting the neighbourhood, although the emissions were already within the required legislation levels.

Second, most companies have no specific environmental decision making tool. Decisions are evaluated using the business decision tools such as cost-benefit analysis. Waltham (case 2) was developing a framework for environmental decisions. Its improvement model is still in a conceptual stage but it seeks to integrate strategically the engineering and business plans. Also, the model should take into consideration short-term activities such as recycling, energy saving and materials as well as long-term leadership action to make the company a credible green company.

Third, as a consequence of the business-as-usual behaviour for environmental decisions, they are strongly influenced by organizational structures. It is less bureaucratic for small decisions in all areas but more so in product development, where every new change needs approval. For large projects, environmental decisions will go through a very structured approach, until they get the positive response from top administration. In the end, the chances of having a new idea approved are reduced, if the idea is not completely aligned to the organisation's main goals, overall strategy or corporate philosophy.

Relationship between environmental decision making and reactive and proactive behaviours

Figure 7.1 shows that companies moving from a reactive to a proactive behaviour tend to also have environmental initiatives to non-manufacturing activities. Initially, they were mostly concerned about meet minimal standards for legislation compliance, evaluating their initiatives based upon return on investment and meeting customer requirements.

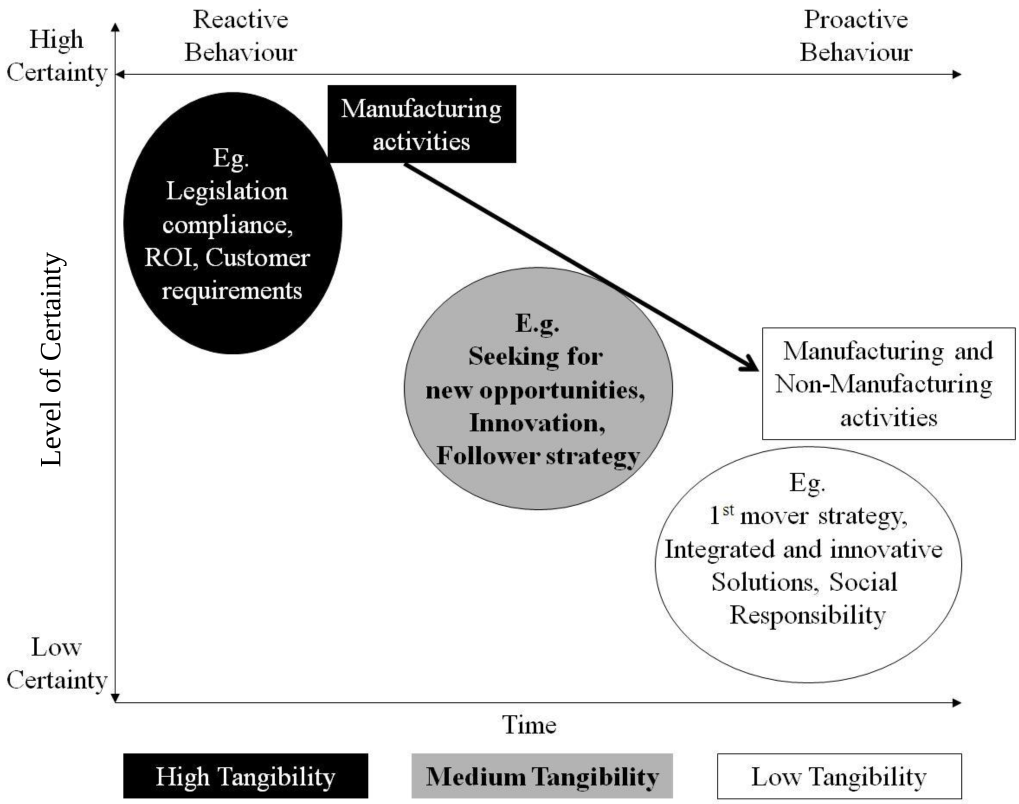

Figure 7.1 - Relationship between environmental decision making and reactive and proactive behaviours

Looking at cases, all interviewees have explained how they moved or should move from a reactive to proactive behaviour, with exception of Thai Garments. For them, it implied doing more than the required by law, anticipating customer requirements, seizing on competitors' experimentation in order to innovate and seek for new opportunities.

It was possible to notice that by doing that, they were incorporating non-manufacturing activities in their range of environmental initiatives. However, it was noticed this movement was associated with a decrease of certainty and tangibility in their decisions. For instance, in manufacturing processes it is fairly easy to control and calculate emissions and cost reductions. Usually, there is little transformation on the product and the environmental gains are strongly associated with efficiency gains, mainly in programmes like energy use, water conservation and waste reduction. These are all easy-to-measure variables and the environmental decision making process has a high level of certainty in predicting the results of investments, new technology implementation, or environmental programmes.

On the other hand, towards the extremes of the supply chain (raw material suppliers or customers) complexity, uncertainty, and intangibility are added to environmental decision making process. Environmental initiatives on the product, for example, may not be accepted by customers although these contribute significantly to environmental impact minimisation. Green supply chain initiatives are also difficult to handle, due to cost increase for lack of certainty in reducing environmental impacts.

Companies that refer to a possible environmental leadership may struggle to clearly justify their investments, and the benefits of their initiatives. These companies, by being proactive and going beyond manufacturing activities, tend to achieve a number of intangible benefits at a lower certainty level. For instance, environmental product design interventions may not necessarily be accepted by customers and green supply chain initiatives such as ISO certification requirement may increase suppliers' costs with little environmental benefits. This also supports why most companies start investing in internal operations and manufacturing processes before adopting product stewardship or sustainable development strategies defined by Hart (1995).

Relationship between environmental decision making and green operations practices

Figure 7.2 supplements the information shown in Figure 7.1. Figure 7.2 shows that companies expand their range of environmental initiatives from manufacturing to non-manufacturing activities.

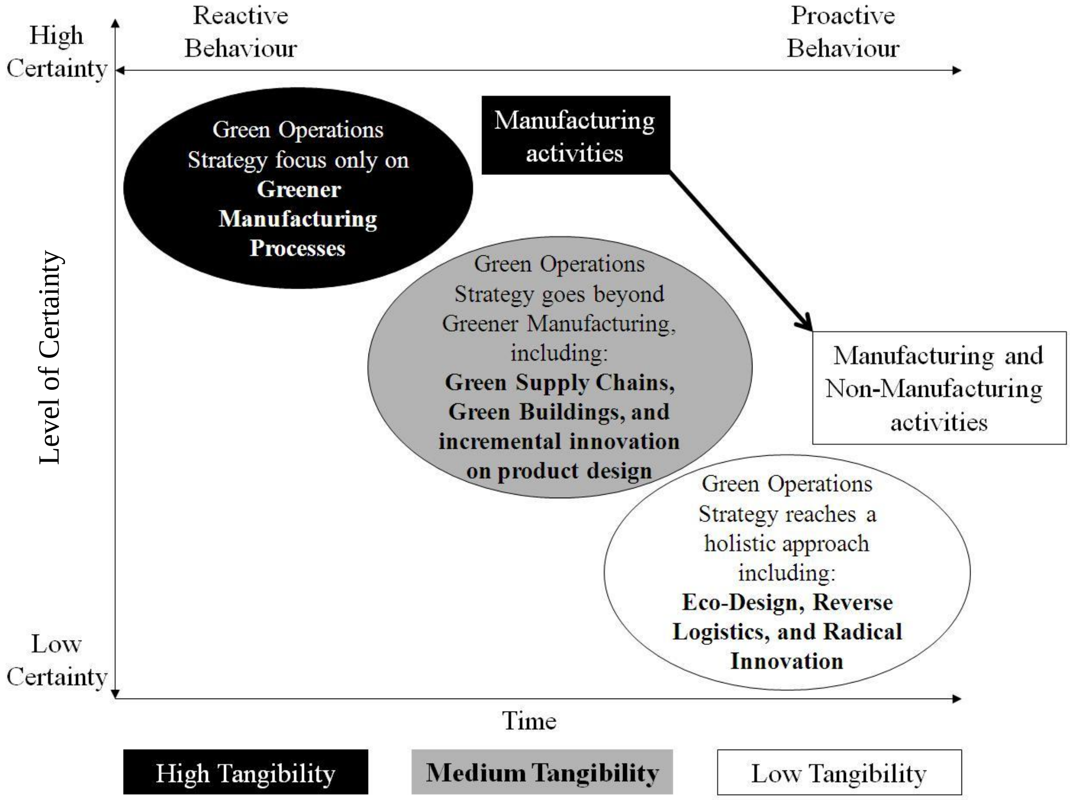

Figure 7.2 - Relationship between environmental decision making and green operations practices

Expanding the environmental policy and actions from manufacturing to non-manufacturing activities implies the use of a wider range of environmental practices. Within manufacturing, companies are mostly concerned with the 4Rs (reducing, reusing, remanufacturing, and recycling) of greener manufacturing concept. The programmes are well defined around hazardous and non-hazardous waste, energy and water consumption, emissions prevention and control.

One step forward is the inclusion of facilities management, for both manufacturing and non-manufacturing areas, and logistics, which are associated with green buildings and green supply chains, respectively. A further step that can be taken is getting closer to Hart's (1995) sustainable development strategy, which combines environmental concerns for both products and processes.

Nonetheless, this research investigation found that the farther the decision is from manufacturing processes the harder it gets, including the understanding of what green means.

Relationship between environmental decision making and internal technical competence

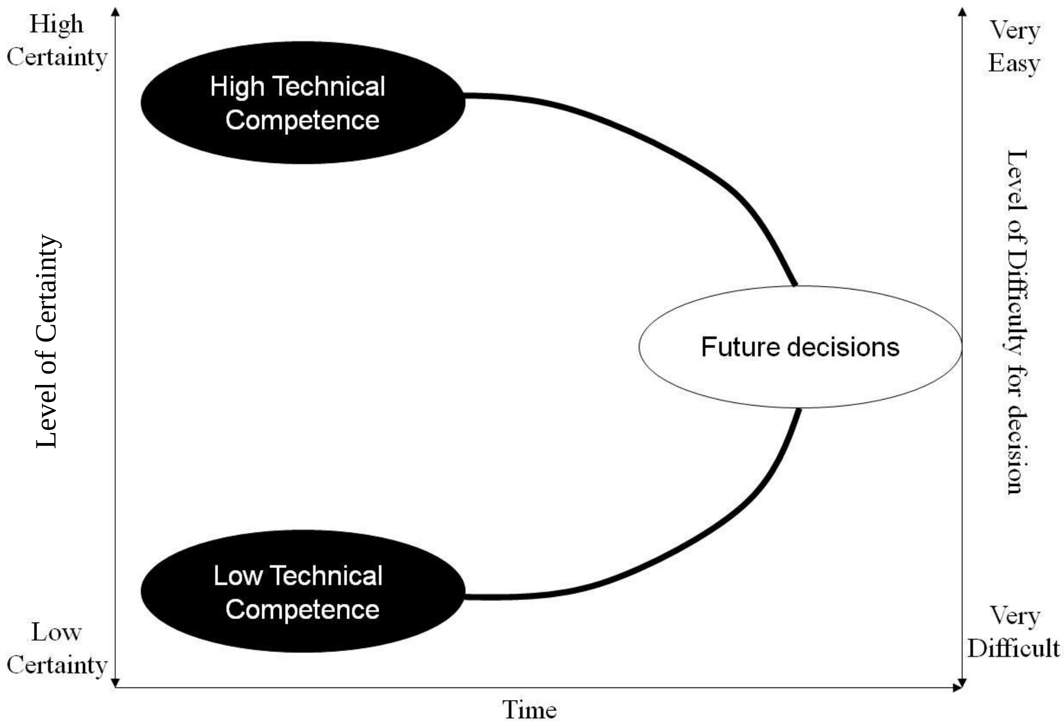

Figure 7.3 - Relationship between environmental decision making and internal technical competence

Figure 7.3 shows that companies with high technical competence will have an easier start when greening their operations function. In fact, the data analysis shows that companies are initially pressured by legislation, customer requirements, or cost reduction policies, and all of which seem to be fairly easy decisions as they are single objective decisions, mainly for companies with high technical competence.

Interviewees (case 8, 10 and 11) reported that the company responds to these requirements in order to continue in the business. Mostly, the initiatives are first implemented in the manufacturing processes; but when they are expanded at supply chain level, and mainly, for product development, they tend to get harder. For companies with low-technical competence (case 9, specially), the start is also difficult as they do not visualise the economic and commercial benefits of environmental programmes. Nevertheless, once they engage with environmental initiatives their future environmental objectives become clearer and the decisions easier.

By migrating from manufacturing to supply chain and product development decisions, companies will deal with a broader set of environmental decision criteria than the usual legislation, customer requirements and cost reduction. If in the beginning, decision makers could understand that the risk of failing in meeting legislation, customer requirements or lowering the production costs would put their business in jeopardy. It is now much harder to infer the impact of their environmental policy on suppliers and green features on the products.

7.5 Comparative analysis between automotive and non-automotive cases

There were significant differences between automotive and non-automotive cases in terms of environmental decisions taken at the corporate level. Because of its maturity and size, and the high environmental impacts from its operations and products, automotive companies tend to have a wider range of environmental initiatives ranging from the construction of plants to end-of-life products. The amount of publicly available information (in the environmental reports) demonstrate that the auto industry has a legitimate concern in disclosing their environmental performance figures. Auto companies can serve as an example to other industries in structuring their environmental decisions. For years, they concentrated their efforts mostly in the process and neglected the environmental decisions towards a greener product. By neglecting the forthcoming stricter environmental legislation relating to the product, the auto companies did not realise that environmental features could be a way to differentiate themselves, and develop a new set of skills to enable both incremental and radical innovation. Their heavy organizational structure with large manufacturing plants and low level of differentiation against competitors ultimately led to price competition, which impose tough conditions for green ideas to flourish. Today, the automotive industry is somewhat dependent on the electronics sector to develop a viable electric car, for instance. Significant advancement in bio-fuel engines were developed by suppliers rather than internally. As a result, the pressure for a greener personal mobility in cities may create new competitors that auto industries cannot visualise at present.

Other sectors can learn from the automotive experience and start developing environmental strategies. Firstly, they can learn the positive example of the auto industry in publicly disclosing robust environmental reports and their wide range of green operations practices, particularly towards non-manufacturing activities. Secondly, there is a strong message for non-auto companies which regard to the fact that they must try to anticipate legislation not only for production sites but also for their products. This PhD investigation has found the textile industry in a similar situation where the improvements in manufacturing and facilities are recent. The social and environmental pressures on textile companies however have now being directed on their suppliers and logistics emissions. If textile companies can anticipate these issues and develop green supply chain ideas in advance, they may avoid future costs or loss of reputation. Similarly, it is expected that the products will be scrutinised in the near future in order to understand their impact on the environment during the use and maintenance (e.g. durability, energy required to maintain, etc) and final disposal.

7.6 Mapping the role of the context for Environmental Decision making

Figure 7.4 shows the context for environmental decision making. It reinforces the link between drivers, decisions, environmental initiatives and the results from the implementation of these initiatives. Equally, it strengthens the role of internal policy in being a mechanism to identify and analyse the drivers, provide support to decisions, and guarantee an effective implementation and evaluation of the environmental initiatives.

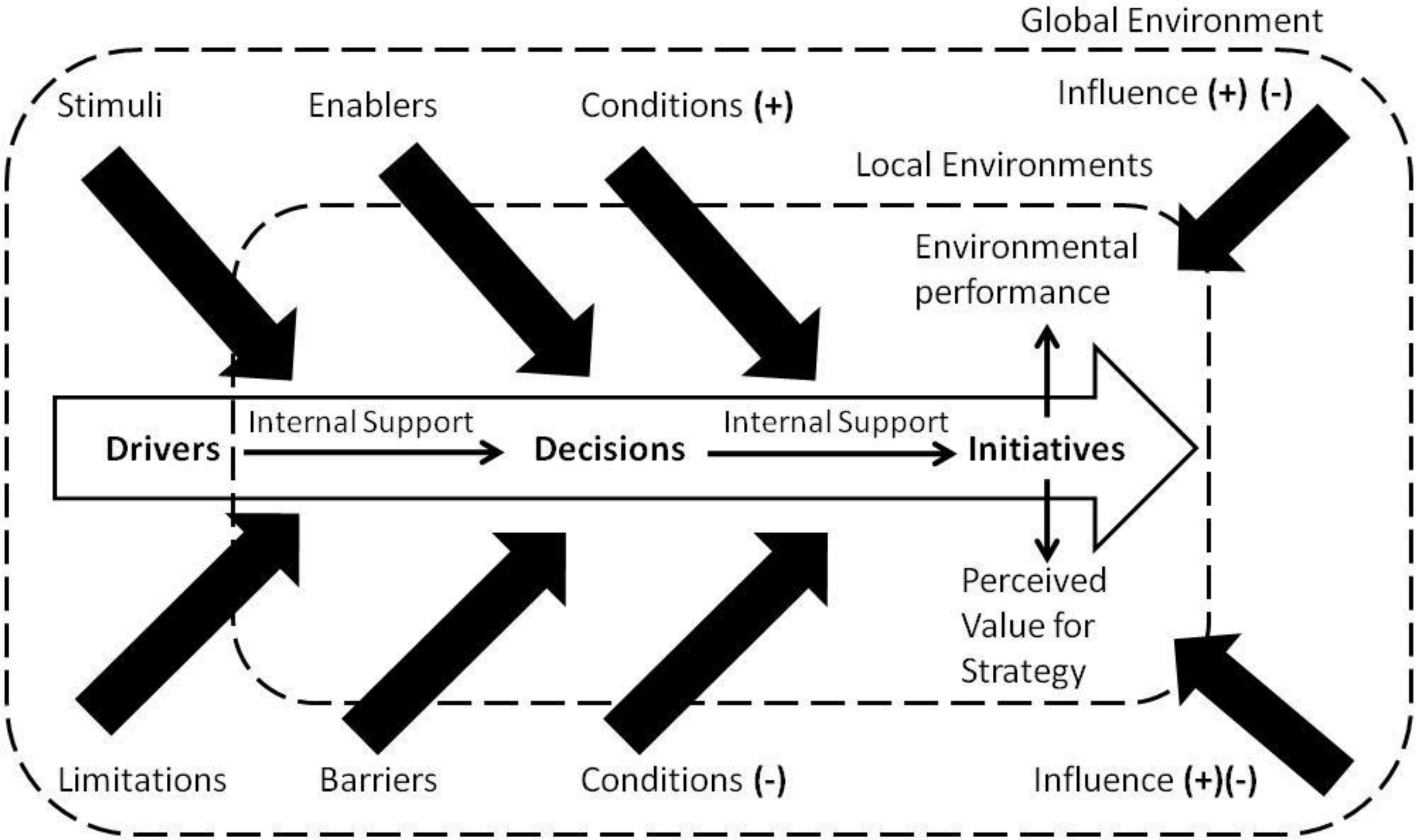

Figure 7.4 – Context for Environmental Decision Making

Figure 7.4 “context for environmental decision making”, shows that from the early stages of an environmental decision (the identification of drivers), the wider environment (global and local ecosystems, society and economy – see figure 1.9) plays a key role in stimulating or limiting the reasons why a company should go green. These stimuli or limitations can be understood as moderators of the process of transforming drivers into decisions. Nevertheless, it is the role of internal policy to understand those from a strategic perspective, select the appropriate drivers, and provide support for the decisions that will have an impact on local and/or global environments. Internal support could work then as a mediator of the transformation of drivers into decisions. Without appropriate internal policies, companies operating in an abundant and stimulating environment may not seize upon more sustainable options. On the contrary, strong internal policies may visualise unsustainable paths, and although the existence of limitations and/or lack of stimuli, they may enforce environmental improvements in order to prepare themselves to better compete in the future. This was the case at JMC in choosing the implementation of the sustainable plant concept for Thailand, UK Carpets in implementing LEED certification in China, CCT developing in-house renewable energy in Thailand, and the new requirements in supplier relationship in TKS. The opposite was also shown true with clear evidence from the cases analysed. In companies operating in developed countries, where there was a clear intention of having stricter environmental legislation, discussion about the global and local pressures for more environmentally-friendly processes and products were taken in a more reactive behaviour. The lack of an internal policy and support can push companies to less profitable environmental solutions, as demonstrated by BLC and Thai Garments, as well as missed opportunities by not scanning and anticipating the future benefits of going green, such as government incentives, cost reduction, amongst others.

Again, once decisions are taken, the global and local wider environments will contribute positively or negatively to the decision's implementations. These enablers or barriers may impact on important operations performance measures for project implementation such as investment, cost, speed, and quality of implementation. Internal support acts again as a mediator identify and weighting the enablers, minimising the barriers, and mostly, dealing with the positive and negative conditions that appear during the implementation process.

Last but not least, Figure 7.4 also shows that the local and global environments will have an impact on how the performance implemented initiatives are measured. Their value for strategy, and even the actual environmental performance, will suffer the interference of local and global ecosystems, judgments of the various segments of society, and finally, the economic circumstances where the company operates.

7.7 Implications for industry

Environmental decisions need to be seen as the means for both actual environmental performance improvement and as a business strategy supporter. Figure 7.5 below illustrates the value of environmental objectives and decisions.

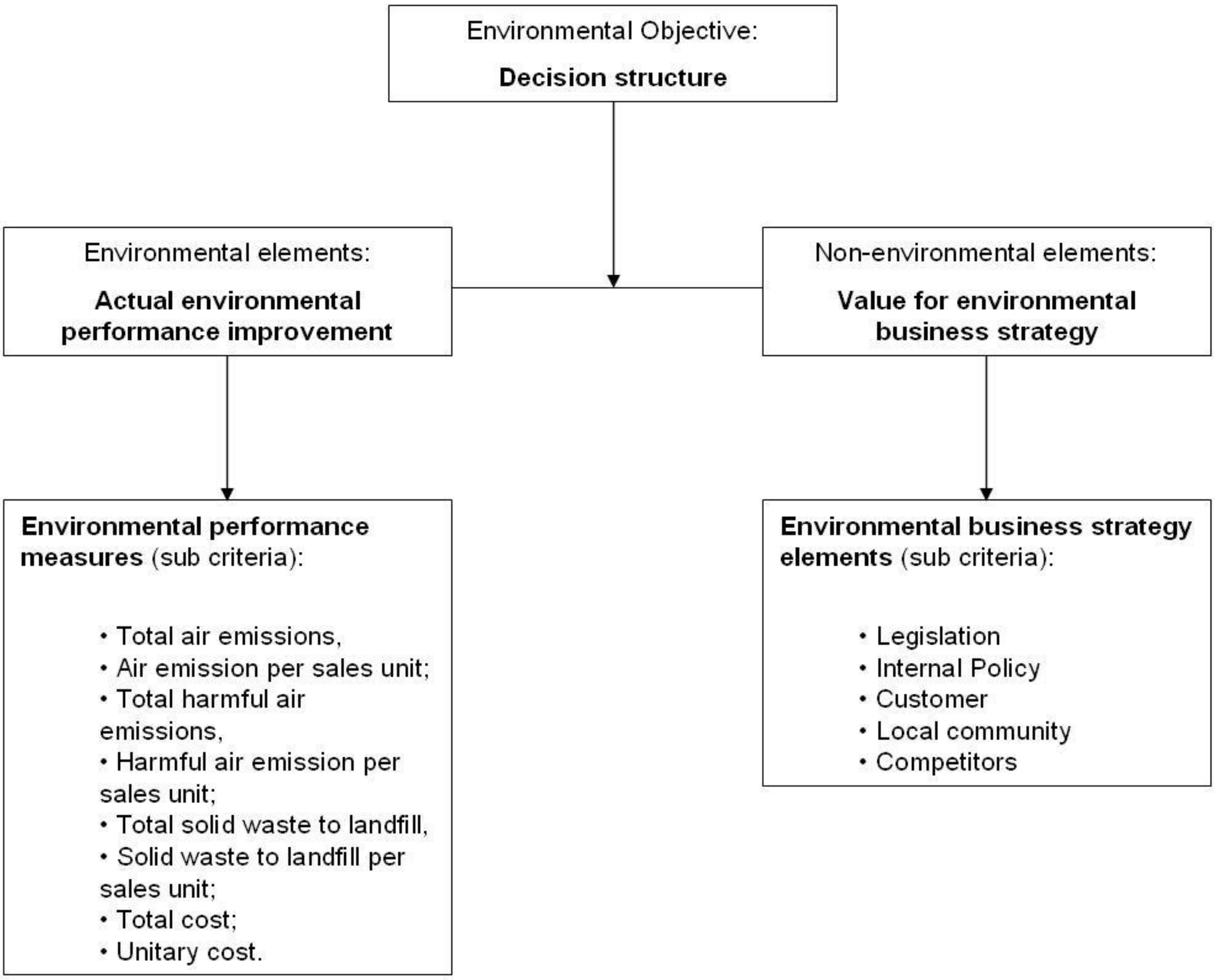

Figure 7.5 – The value of Environmental Objectives and Decisions

This investigation provided evidence of how environmental decisions were evaluated under two main dimensions: environmental impact minimisation and value for environmental business strategy. For instance, JMC's sustainable plant policy associated with a number of practices with uncertain tangible financial and environmental results is one example. JMC claims that their actions are beyond mere marketing and public relations efforts – they are part of experimentation of technologies that may strategically position the company in a better position in the future. Waltham has shown appreciation on how to accommodate environmental initiatives with different payback analysis for strategic reasons. Because AGD was able to link the long-term business and environmental strategy, they managed to achieve results that combined gains in sustainability, profitability, corporate image, and relationship with government and environmental agency. The water-born paint shop and landfill gas project shows clearly the long-term environmental strategic issues being discusses and evaluated.

The case of BLC (product development department) shows that failing in visualising the value of environmental decisions for business strategy can impact on the actual environmental performance of the company. The short-term focus on actual environmental gains can paradoxically affect negatively its future performance, preventing the company from achieving higher exponential gains. The reason behind this is the fact that neglecting the strategic side of environmental objectives and decisions may impede the company in building stronger internal policy, environmental competence, strategic partnerships, amongst other important factors necessary for the development of innovative solutions, both radical and continuous improvements.

A clear view of these factors instead can contribute for the environmental strategic positioning of the company as it happened with UK Carpets. Their ‘way forward’ is set also with strategic goals such as “to lead the sector by 2015”, which although carrying a subjective dimension can be associated with quantitative targets like reducing emissions by 10%, and the internal policy message can permeate the company better fostering innovative ideas for environmental improvements.

TKS and CCT have also demonstrated an understanding of the strategic value of environmental decisions. TKS’s discourse contains various elements about how the world has changed, the new demands in international trade, and the future cost and implications of not going green today. CCT’s intention in building a biomass plant due to the increasing oil prices show how the company tries to scan the economic and environmental context where it operates before taking strategic decisions. They could relate the biomass project as an environmental initiative that will contribute to the company’s long term competitiveness by having energy security from a renewable-green source.

Most managers (except from those in JMC) felt they do not have a robust and structured approach for environmental decision making. Decisions are sometimes based on experience using rudimentary tools which examine the financial performance of alternatives.

However, some case companies use decision structures making environmental decisions go through the same path and procedures as any other business decisions. For instance, UK Carpets has taken decisions based upon an isolated driver (e.g. customers) without considering the implications of other important drivers (e.g.

competitors, legislation, and environmental performance). Similarly, BLC has made investments to improve its image without a strategic input.

In one case, environmental decisions were viewed as easy but getting harder (UK Carpets, case 8). For instance, the environmental decisions were considered easy because the interviewee felt it was obvious what should be done – e.g., a requirement by the law or by the customer. It was likewise for TKS (case 10) and Waltham (case 2) Nevertheless, they predicted future complications as the company meets basic requirements, so a more strategic and proactive approach will be needed.

Three of the cases (1, 3 and 10) had a very structured approach for business decisions which end up being used for environmental decision making. The issues relating to an understanding of what green means in terms of products, process, and technology when taking a decision were also brought into consideration.

A special context was also found in sectors where environmental-related legislation was very strong (e.g. hygiene for food processing and safety for chemical). In these cases, meeting the legislation was very close to meeting customer requirements, as well as the industry environmental benchmarks. Nevertheless, these companies were also moving towards more proactive behaviour due to brand image, cost reduction opportunities, and benefits of environmental management systems certification.

7.8 Final Considerations and Insights from the Case Analysis

From the cases analysis, five major conclusions are drawn:

(i) *When companies expand their environmental initiatives to non-manufacturing activities, the complexity of environmental decision making increases;*

It was noticed that the decision making teams within manufacturing activities had a clear view of what green means, and due to the strong link between firm and manufacturing performance and environmental technologies (Klassen and Whybark, 1999), the environmental manufacturing decisions were relatively less complex than other areas such as in supply chain and product development. Changes in the product are usually difficult to measure the level of greenness as well as the future success or failure of new innovations.

(ii) *Ideas come from different sources depending on the nature of the problem.*

Size and complexity of environmental initiatives depends on the source of ideas. This is particularly important because the environmental policies could include the use of solutions providers at the early stages in order to facilitate access to valuable information and ideas to more players within the different industrial sectors.

Large projects undertaken by the environmental departments have strong influence from external sources such as consultants, industry federation or associations, environmental protection agencies, universities, suppliers, etc. Not differently, complex solutions tend to have external sources that are considered appropriate to a successful implementation and minimisation of various risks (technical, organisational, etc). When a company is deciding on a large environmental investment or initiative, it is very likely that there will be more than one department involved in the decision making process, including in the stage of raising ideas. On the other hand, with small projects personnel are allowed to come up with ideas, mainly for continuous improvement.

(iii) Drivers and measures to environmental decision making within manufacturing activities tend to be clearer, more tangible and easier than those towards non-manufacturing activities;

As found in the environmental reports analysis and confirmed in the case research phase, car companies are implementing competing environmental technologies for product design. This is evident in their initiatives in fuel and material diversification. However, even smaller changes in components are difficult to be evaluated because these are connected to the whole of a car.

For the manufacturing and closely related activities (such as inventory, in-bound logistics), the measurement system is more mature, and there is less influence of uncontrollable factors (e.g. customer behaviour) in the decision making process. Local and global pressures towards the process are far easier to be predicted than the future environmental demands for the product.

(iv) *Environmental decisions are dealt rather similarly to other business decisions although there are exceptions where environmental concerns are weighted higher than other traditional business measures;*

Environmental concerns are mostly considered as a threshold to be overcome (emissions limit, ISO certification, level of recyclability, etc). In the occasions (cases 1, 4, 5, 8, 10 and 11) in which environmental concerns were really the main driver for an environmental initiatives, the importance of having an environmental strategy seem to be emerging. Where the ecological motivation is blended with economic and performance benefits, there seems to lead companies to lack environmental decision making models and a proper structure to support environmental decisions.

Companies that want to lead the environmental race will need to internalise environmental issues and develop a strong environmental policy beyond manufacturing. When environmental concerns hit the main stream of business, environmental criteria are better weighted in the business decision making, instead of being an add-on feature.

(v) *A systemic model for environmental decision making is necessary for complex and large environmental initiatives;*

Environmental decision making models will need to respect the current organizational structures that are already in place in the companies. This means that a structured approach for environmental decision making would be better accepted for complex and large environmental initiatives and more radical changes; while the continuous improvement initiatives could continue with unstructured approaches.

7.9 Recommendation for greening global supply chains

All companies investigated in this study were involved in global trade to some extent. The degree of international trade varied from export to green field investment; nevertheless, international trade was considered one of the factors influencing the drivers for environmental initiatives. International operations expose the companies to different (and perhaps, stricter) legislation, customer demands, and strongly influence the internal policy of an organization. Therefore, this study provides directions on green global supply chains. Based on the case analyses and literature review, the following sustainability directions in global supply chains can be raised.

7.9.1 Anticipate government regulation in production locations

As environmental awareness progress worldwide, companies will need to anticipate environmental regulations in the different markets they serve and production location they operate. Companies that experience stricter regulation in the domestic markets are able to learn lessons and contribute in the discussion of future regulation development. Likewise, those that prepare for forthcoming regulations will be able to seize upon smother changes (e.g smaller and more planned investment) as well as play a role in designing regulations in other countries that may implement them in the future.

Three company cases illustrate this issue very well. An auto company has transferred the greener technology for the paint shop from Germany to USA, creating a new environmental benchmark for paint shop emissions in US auto industry. Another auto company uses its awareness and experience with the Japanese landfill legislation in order to create a higher level of preparedness in Thailand where the environmental legislation lacks actions towards end-of-life vehicles. Last but not least, the carpet manufacturer brings customer requirements for US and European plant to its new production site in China by certifying it with the American Green Building LEED label. Basically, the company is using production benchmarks of the American market in a Chinese plant which will put it ahead of legislation and set new environmental benchmarks for China as a production location.

7.9.2 Environmental concerns in the choice of the host country and technology

Regardless of its limitations, Environmental Kuznets curve (EKC) shows that different countries may have different environmental priorities. While developed countries may be concerned about CO_2 as the major pollutant, developing countries might be focusing on the elimination of harmful emissions such as fine particles and SO_2. Hence, to maximise environmental gains, the choice of the host country's location needs to consider local critical pollutants alongside traditional criteria such as distance, quality, production costs, infrastructure, as well as other location factors (Hill, 2007).

Depending on the choice of the technology and the nature of the business, local critical pollutants can be worsened or alleviated when a new production facility is installed.

As part of global environmental impact minimisation, finding the best location for reducing the extent of outbound logistics is crucial. Compared to inbound logistics, outbound logistics is usually less efficient as finished products usually have a lot of empty space in their interior. Moreover, protecting against damage to finished goods will tend to demand more energy to be expended; therefore being close to the main market is likely to reduce the overall impact. In two cases, it was found evidence of establishing new plants closer to the companies' main markets rather than at locations to lower production costs (case companies GM and AGD).

7.9.3 Identification of and adaptation to the host country's sustainable opportunities

Due to their focus on a global scale, companies may be blind to local sustainable opportunities. However, such opportunities may be technically feasible, economically viable and aligned with market requirements.

Three of the company cases adapted their products to take advantage of local sustainable opportunities. For the Brazilian market two auto case companies (GM and Volkswagen) have acquired expertise in producing flex-fuel engines and adopted the technology as standard for their models sold in that country. Another case company (AGD) found use for natural fibres found in Africa in order to reduce the weight of the car. The general recommendation though, is given by Geffen and Rothenberg (2000). They discuss how suppliers can be important in environmental innovation. In a global context, this discussion needs to take into consideration the local expertise and knowledge about the availability of abundant renewable resources that may not be visible from the company's headquarters.

In its plant in the US, case company AGD has also experimented with new green technologies to find energy to power its plant using biogas from the local landfill. Another experience in case company JMC relates to the use of solar panels in its production facilities in Thailand – a project without requirements of financial payback. Indeed, to bring a strategic view for environmental initiatives is extremely necessary during its early stages. Case company Waltham produces a luxury automotive brand and adopts an extended payback period for environmental projects (from two to five years). In the environmental report, case companies GM and Volkswagen highlight that they have designed modular production systems in conjunction with supplier parks, which eliminate inbound logistics from key suppliers. The benefits go beyond energy conservation in production since some of the protective material is not necessary, thus reducing the waste from outbound logistics operations.

In short, the practices described (use of local sustainable opportunities, experimentation of green technologies, and more sustainable production systems) have proved successful in promoting profitability and better environmental performance because the companies had a strategic view of their environmental initiatives.

7.9.4 Use of green supply chain systems and transfer of green technology in the global network

Most companies have stressed the environmental issues regarding their purchasing, logistics systems, and related issues (packaging, waste, inventories level, etc). Due to the existence of good railway networks European and Japanese companies have tried to change their inbound and outbound logistics from road to rail.

Most of the case companies have also structured systems to share knowledge with suppliers and with other associated business and production units. This included the benchmark of environmental performance and transfer of environmental technologies. Companies with strong expertise in green technologies become attractive in a global market with a scarcity of environmental leaders. The main benefits include joint ventures, royalties for green technologies, and an improved image among their customers.

Although the traditional path of technology transfer is from industrialised to developing countries, green technologies may be transferred in both directions as many developing countries can evolve greener processes due to early investments or the availability of cleaner resources.

7.9.5 Consider the backwards flow when designing the global supply chain network

In addition to the concerns regarding forward flow in the supply chain, companies will now have to also consider the backward flow in their managerial decisions for location, product design and partner to cope with the product recovery legislation. One case company (FAC and WMC, case 7) shows the relationship of a Parts Distributor and a waste management company. Besides outsourcing reverse logistics, the company is through this partnership trying to extract value from scrap while keeping with good environmental stewardship.

From its environmental report, it was possible to learn that Toyota has already taken advantage of its expertise in reverse logistics to play a role in the development of take-back legislation in China. Reverse flow is a concern not only in the end-of-life products (Fleischmann et al, 1997), hence; bigger companies (GM and Toyota) have targeted zero landfill policies for production sites. Nevertheless, in order to achieve zero landfill policy globally the company is dependent on recycling infrastructure that is out of their control.

7.9.6 Use a value network perspective when developing a global environmental strategy

The history of the automotive industry has noticeable landmarks from a conceptual perspective. Initially, like all other manufacturing companies, car manufacturers were only concerned with processes. Production processes were observed, analysed and managed in isolation from the other related production processes. Later, scholars and practitioners broadened their views towards job shops, assembly lines, factories, logistics and finally, supply and value chains – the highest level most of companies are considering in the managerial scope.

There is an immense progress by migrating from narrow to wider approaches and concepts, and now we face a need for another transition: from supply and value chains to value networks. Alongside with the benefits of a wider approach, there are challenges and complexities added for management as well as policy makers. Nevertheless, the progress is urgent, necessary, and eventually, inevitable for most of manufacturing industries, especially car manufacturers.

Businesses are facing fast-changing environments and newly emerging pressures which are creating a daunting task of rethinking the way we manage companies, in particular, large enterprises like in the automotive sector. For instance, environmental and sustainability issues are in the need of being integrated nonetheless in a cost-effective way, preferably, adding competitive advantages to the company. For a long period of time, most of the manufacturing capabilities were internal and with focus on efficiency gains only. Likewise, the value of the companies was mostly assessed by their physical assets as well as their financial performance. However, within the new modern economies, the value of intangibles has increased and the old techniques and practices focused on efficiency have became obsolete. In the 21st-century global economy, the creation of value and the speed of innovation are key to acquire and maintain a successful position in the market. Within this new context of globalised, complex, dynamic, and diversified economies, we suggest the adoption of the value network concept into the management of automotive enterprises in Europe.

The debate about supply chains and value networks is still underway in academic terms. In 1982, Keith Oliver, a Booz Allen Hamilton executive came up with the term “supply chain management” (Sherer, 2005). Almost 15 years later, in 1997, the concept “value network” was coined by Christensen (1997). Being older, the term supply chain management has been modified over time, and although the definitions of supply chain and value network may sound similar, one should note their intrinsic differences. The following outlines the differences:

Supply chain concept:

> *APICS defines supply chain as: "the processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier-user companies; and the functions within and outside a company that enable the value chain to make products and provide services to the customer" (Cox et al., 1995)*

Value network concept:

> *"The value network is the context in which the firm operates, assesses customer needs, responds to customer demands, gets resources and deals with competitors. It is the collection of upstream suppliers, downstream channels to market, and ancillary providers that support a common business model within an industry. When would-be disruptors enter into existing value networks, they must adapt their business models to conform to the value network and therefore fail that disruption because they become co-opted." (Christensen, 1997)*

For instance, while supply chains resemble the idea of a linear flow; value networks describe a more real-like structure resembling a web composed by various interconnected nodes. While, supply chain concept emphasises the traditional performance measures such as cost, efficiency, speed, etc; value network approaches subtle managerial issues like inter-organisational relationship, capabilities and competences, intangible assets, information flow, etc.

Indeed, there is an enormous gap between supply chains and value network approaches and the migration from one to the other is a challenge. However, the embedded risks of not doing it are much higher as it can lead the company (or even a sector) towards stagnation, poor performance, and lately, a complete collapse.

By adopting a value network approach, companies may find hidden opportunities for environmental improvements in suppliers, transportation infrastructure, commercial customers, environmental agencies, amongst other important stakeholders of the automobile industry.

7.10 Chapter summary

We are in the early stages of greening global operations' supply chains. The focus during the 1970s was mainly on pollution control, which moved towards pollution prevention in the 1980s. In the 1990s, we experienced the emergence of environmental management systems (ISO 14000 series), which contributed to the spread of common standards across the globe. Then ISO 14001 raised concerns about third parties in the process prompted by the already high-level of outsourcing in the 1990s. Nevertheless, in the 2000s we have started seeing the establishment of a green supply chain philosophy. The various social and environmental crises of global operations in the past, such as Nike in Southeast Asia, Shell in Nigeria, Exxon in Alaska etc. (Hill, 2007) have resulted in an increased weight on sustainability factors for the top management of global companies. Today, surrounded by different pressures from several stakeholders and operating within different countries, cultures and environmental priorities, companies will need to review traditional concepts for globalising operations. Cost reduction, profit maximisation and market share must be considered alongside risk assessment, environmental performance and social constructs in the corporate strategic decision making process.

As shown in the literature review, various authors have highlighted changes to the rules of competition from mere efficiency gains (cost-based competition) to incorporate agility, adaptability, alignment, and now sustainability performance. The results from primary and secondary data shed light on basic directions that could be taken in order to obtain higher benefits from environmental initiatives in the global market, which could include: cost reduction (productivity gains, environmental liabilities, health and safety costs, waste minimisation), product and process simplification, a better image, access to new markets, attractiveness for partnerships, etc.

From the cases analysed the major directions for higher levels of sustainability can be identified. These are:

(i) Environmental concerns in the choice of the host country and technology,

(ii) Identification and adaptation to the host country sustainable opportunities,

(iii) Use of green supply chain systems and transfer of green technology in the global network,

(iv) Consideration of backward flow when designing the global supply chain network,

(v) Move towards supply network concept.

These directions should not be followed in isolation. On the contrary, organisations should try to combine all directions in order to maximise results. The green operations classification can help companies in pursuing such directions and taking decisions. The framework, which is presented in the next chapter, seeks to improve strategic environmental decision making, suggests green operations practices for each activity of the operations function, namely: green buildings, eco-design, green supply chains, greener production, and reverse logistics. The author also highlights the importance of innovation in the process of going green. As companies progress to further levels of complexity in global supply chains, they may encounter in taking these directions a suitable path to follow. By improving the process of environmental decision making, organisations will ultimately improve their own future decisions (what to do), and consequently, their environmental performance. The green operations framework and a systems methodology to improve environmental decision making are presented next in Chapter 8.

Chapter 8 – Development of a Proposed Model for Environmental Decision Making

8.1 Introduction to Green Operations Framework and the *GRASS* Model

This chapter presents a proposed model for environmental decision making and its development stages. It is important to remember the steps undertaken to achieve the version of the model presented in this Chapter, particularly shown in Figure 3.3 – The Chronology of the Research Project. As described in the Methodology Chapter (Figure 3.3), the *GRASS* (Greener Approach to Systems Strategy) Model is derived from insights gained from the Green Operations literature and then supplemented by systems thinking theory, and finally contrasted with the primary data from interviews and focus groups from the case research phase. The model could actually be understood as an evolution from a green operations framework, which would be considered its first “stage”. The Green Operations framework was itself derived from the literature, particularly from the classification of Green Operations Practices (Figure 2.2 and 2.3); while the *GRASS* model consisted of an adaptation of the framework for more generic environmental decision making and policy. The model itself received inputs from the strategy and decision making (particularly, systems thinking) literature, practitioners, and was tested in a real environmental decision making problem.

8.2 The stages of model development

The model was developed in three main stages. The first stage included a literature review on the theory of green operations and an evaluation of its practice through the analysis and benchmarking of environmental reports (presented in chapter 4). From a theoretical perspective (supported by evidence in secondary data), a green operations framework was developed (see Figure 3.4).

The framework, however, imposed a rigid structure for the project's research design since it could not be adapted to strategic decisions within the activities of the operations function. Although the framework is theoretically-sound, its scope for application, test and evaluation must occur for environmental strategy at the firm level. Hence, the introduction of systems thinking (Soft Systems Methodology - SSM) in order to adapt the framework for department-level strategic decisions was necessary. This adaptation is considered the second stage of model development.

Last but not least, the systems model (from now on called *GRASS* model) was tested and evaluated through two focus group activities. The lessons learnt from the focus group were used to improve the model in conjunction with the findings from the case study research presented in chapter 7.

8.3 The Green Operations Framework

This section presents a generic framework for Green Operations, providing the idea that there are green practices that could be included in every phase of the operations function.

Figure 8.1 shows the activities of the operations functions organised into six main blocks: (i) production capacity (planning), (ii) process and product development, (iii) supplier relationship (and selection), (iv) production, (v) in-bound and out-bound logistics, and (vi) after sales.

The activities of operations function appear in the centre of the framework, where the Green Operations practices also reside. They are represented by “existing environmental practices for manufacturing”. The box labelled “innovation” shows that Green Operations may require the development of new practices, technologies and production systems.

There are two basic strategies: incremental innovation through successive improvements of the current production system or more extensive changes to the production system. In each case, there is a need to analyse the impact of the proposed production system on the company’s environmental performance.

As well as analysing the impact of the proposed changes in the production systems, it is fundamental for the successful development of the framework and the implementation of the Green Operations Practices (GOPs) to find out the effectiveness of this framework, and the impact of the five GOPs on the company’s environmental performance, which does not have any clear criteria yet. As an example, Rothenberg et al. (2005) suggest an Environmental Benchmarking for automakers, which involves four categories: (1) regulatory compliance, (2) gross emissions, (3) efficiency, and (4) life-cycle analysis. Therefore, an analysis of the contribution of GOPs to each of those four categories could help companies to take greater advantage of this current framework and the future model that will be developed from it.

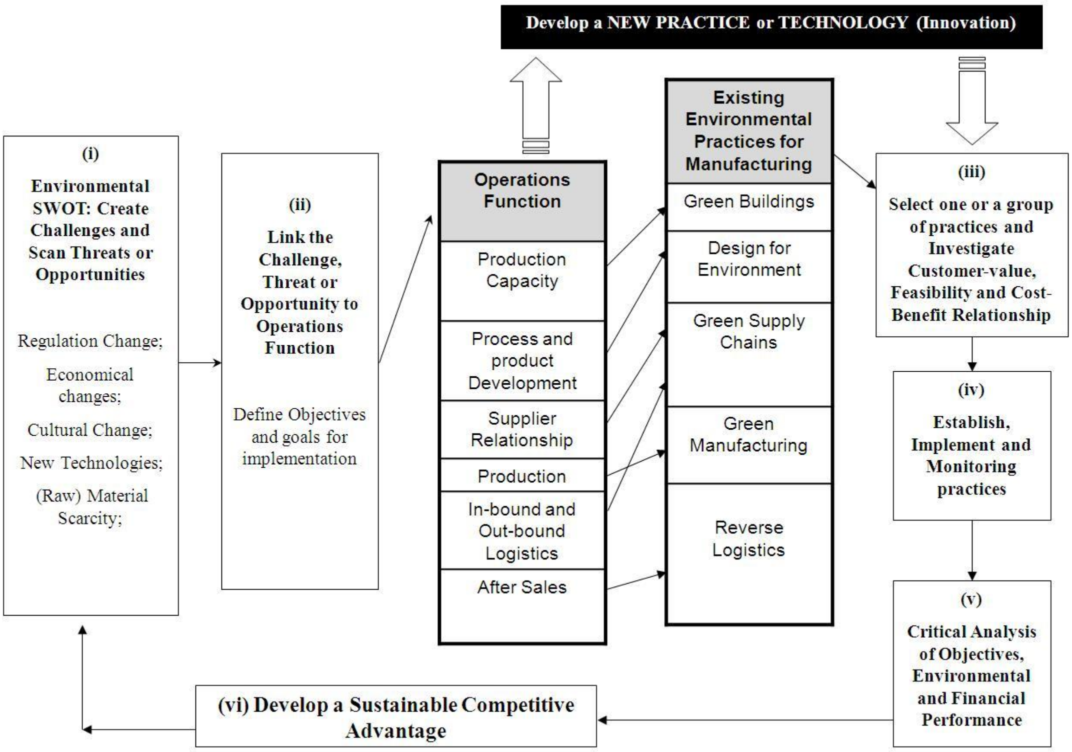

Figure 8.1 - General framework for Green Operations.

The framework seeks a dual benefit by using a strategy technique (SWOT) and integrating environmental issues in the corporate strategic agenda. Using an environmental SWOT may enable the company to have better results from the investments of its environmental policy. On the other hand, understanding the green opportunities and practices related to the broad processes of operations may motivate the top administration to develop a more sustainable corporate strategy.

Step (i) is to perform an environmental SWOT analysis. In this step the company should run sessions to identify its strengths and weaknesses regarding environmental issues as well as possible threats and opportunities. Taking into consideration the life-cycle approach is important to visualise external factors that might affect the company. By using the environmental SWOT analysis companies can contextualise the framework and green their operations based upon local and global scenarios and align the environmental business practices to the corporate and operations strategy.

Step (ii) is to link the challenges, threats, or opportunities to the operations function. Managers need to associate the most important and urgent challenges, threats, and opportunities to the value chain of their organisations. According to their processes and internal analysis (strengths and weaknesses), they can establish environmental objectives and goals, methods for implementation and measurement.

Step (iii) involves the selection of one, or a group, of practices and the investigation of customer-value, feasibility and/or cost-benefit relationships. At this time, it must be assured that the environmental objectives and goals have enough support from top administration and the employees and that the suppliers are competent to implement and monitor these. Finally, the cost/benefit analysis should indicate a status of economic viability or strategic fit for the environmental practice. The value of these actions for customers is measured; however, even if there is no customer support, some of the practices should be implemented for avoiding future problems with regulation.

Step (iv) is to establish, implement and monitor practices related to daily procedures and instructions of those green operations practices. Having an environmental management system is recommended as well as running periodic PDCA (plan, do, check and act) cycles. These may enhance the chances of continuous improvement, which is particularly important after radical innovations.

Step (v) is the critical analysis of objectives, environmental and financial performance. The definition of indicators and benchmarking methods to analyse the objectives and environmental and financial performance is essential to organisational learning in environmental management. The benefits sometimes can come from a different area where the practice was implemented (e.g., design for eco-efficiency: implementation is in design, however, the results are in the product use). Therefore, detailed and systemic analysis should be combined to a better assessment of the organisation's progress towards the development of a sustainable competitive advantage.

Finally, step (vi) is to promote the development of a sustainable competitive advantage, which consists of achieving a privileged position in the long-term, ahead of competitors, without damaging the ethical image of the company.

The next section provides a contextualisation of the Green Operations framework for the automotive industry.

8.4 Illustration of the Green Operations Framework in the Automotive Industry

An illustration of the framework to the automotive industry follows below. It is important to highlight that step (i) employs the Environmental SWOT, associating the threats to the automotive industry to the broad processes of a company's operations function, which is part of step (ii). Moreover, the current example of the framework illustration considers the end-of-life of the vehicles as the most urgent and important threat to take actions against. If these premises change, it could affect the following steps: the link to operations function, investigation of customer-value, the feasibility and cost-benefit relationship, monitoring, the critical analysis, and the development of a sustainable advantage.

Environmental SWOT and its link to the operations function (Steps i and ii)

For the purpose of this illustration, only the threats and their respective implications have been taken into account. Even though the challenges and opportunities may vary according to the local context, nevertheless, it is possible to think of some global threats that are likely to affect the car industry worldwide.

(1) Zero Emission Vehicle Regulation: California is leading the drive towards zero emission regulation. Should the policy be followed in other cities (or countries), companies that are already engaged in using cleaner fuels would have an advantage. The implications for the operations function would be in the design and manufacturing activities. The supplier relationship could be also affected; however, the predominant concerns are focused on the ability to produce hybrid or electric cars.

(2) Scarcity or price increase for oil and raw materials: Given an estimate that China will produce over six million vehicle units in 2005, it is expected that there will be significant increases in imports of metals. Moreover, the large transportation system in China is based on gasoline and diesel fuels, which would dramatically increase China's dependence on oil imports. "A sobering fact is that if China's vehicles per capita were the same as the United States, the oil demand in China would exceed worldwide oil production by 18%" (Zhu et al, 2007).

The use of different material (plastics or magnesium) may have a positive impact on companies' environmental and financial performance. Moreover, a shortage of oil could lead to a price increase, and therefore would make other alternative fuels viable. The use of renewable fuels such as ethanol or biodiesel will probably be related to the strategy for the national energy matrix (e.g., flexible fleet fuelling and biodiesel from mamona seeds in Brazil). The environmental benefits of using electricity or hydrogen to run cars are dependent on the way they will be generated. Besides product design, manufacturers will need to produce reliable cars using these new technologies; thus, manufacturing should also be on the environmental strategy agenda.

(3) Tighter regulations on gross plant emissions: Some companies have moved their operations to developing countries for various reasons such as low labour costs, fiscal incentives and less strict environmental regulations. However, developing countries are starting to increase the pressure to reduce gross emissions from manufacturing plants. Therefore, the impact might be on the construction and operation of these plants.

(4) Final Disposal Regulation: Another forthcoming threat for the automotive industry arises from the final disposal of cars. There is increasing pressure on car automakers to assume responsibility for their scrapped vehicles. In this case, the threat links to their after sales activities; thus, a structure for disassembly of cars will probably be needed.

Investigating Customer-value, Feasibility and/or Cost-Benefit Relationship (Step iii)

Taking a hypothetical example, let us suppose the higher pressure for a company involves the need for final disposal of cars. Thus, if manufacturers are required to deal with this aspect they should select Reverse Logistics and try to excel in it. As a consequence, companies that recognise the residual value of some discarded components and have efficient collection networks, will be able to apply the reuse obligation strategically and even commercialise the scrap, thus turning the threat into a sustainable competitive advantage.

Although Reverse Logistics might be the core competence, other environmental practices (mainly Eco-design) can play an important role. This happens because Eco-design techniques could make a car use less harmful substances, become easier to disassemble, and help the process of recovering the scrap.

Implementation and Monitoring (Step iv)

Once practices are selected and there is administrative, technical and financial support to implement the Reverse Logistic programmes, the key partners, suppliers and customers must be involved to enhance the possibilities of collecting end-of-life products and providing a better destination to its components (reuse, remanufacture or recycle). The first decision regarding the implementation of those programmes may be to “buy” or to “make”. Should the car manufacturer concentrate on its core competence and outsource end-of-life collection, separation, disassembly to other companies? Should a disassembly plant follow the pattern of a few large and centralised plants, or should it be various small and decentralised plants? Regardless of the choices, monitoring the recovery processes may still be the responsibility of the car manufacturer. Incorrect use of a product recovery network inhibits the car assembler from taking advantage of valuable components in the scrap and, what is worse, may affect negatively the image of the company if the final destination is not appropriate.

For these reasons, the sales centre could be used as an information provider for collection or even as a collection point. Key customers, such as rental companies and the public sector could return their end-of-use cars to the manufacturer or a responsible third part in the recovery process.

Critical analysis of objectives, environmental and financial performance (Step v)

For a Reverse Logistics system, a number of environmental goals, may be established such as the number of recycled cars, average cost of collecting a car, time of disassembly, etc. Internal and external benchmarks are vital to the company’s analysis of its performance. The definition of indicators that allows the company to undertake a critical analysis need to be carefully scrutinised, because the goals might need to follow legislation or be correlated to the current production as it has been set for other products, such as tyres in Brazil. Costs and time of recovery may be higher for new markets where the infrastructure for disassembly could be non-existent or the collection more difficult.

Having relevant indicators would provide the company a better direction for managing the backward flow of products and materials.

Develop a sustainable competitive advantage (Step vi)

It is expected that first movers can develop expertise in Reverse Logistics and a better use of the returned components. Learning or experience curves will probably make undertake the Reverse Logistics process in a cost effective manner, allowing the company to have a superior environmental and financial performance.

Limitations of the Green Operations Framework

The general framework that has been presented here is an attempt to consider specific strengths or weaknesses from the context of a given company. Although further empirical research is necessary to better understand the value of these practices and the applicability of the framework in different companies and sectors, it is believed that the union of a SWOT analysis to Green Operations Practices into a framework using a PDCA cycle is progress towards better sustainable decisions in manufacturing organisations. However, because the framework focuses on the higher levels of environmental decision making, it may need to be adapted to departmental-level decisions.

This is one of the limitations of the author's work, which was developed against a theoretical background. However, as work-in-progress, this study has value for bringing Green Buildings into the discussion of operations management, which was rarely involved previously. The authors propose that the framework will be further developed to become a significant tool to help organisations in their pursuit of a sustainable competitive advantage. For this, it will need to be empirically applied with top administration for strategic environmental decisions.

8.5 The *GRASS* model

This section presents the *GRASS* model (*GRASS* stands for Greener Approach for Systems Strategy) which consists of three major phases (A, B, C) and eleven activities (A1 to A5, B1 to B3, and C1 to C4) and the potential flow of activities. The three phases are (A) Problem identification or objective definition, (B) Development of alternatives, (C) Selection of alternatives, implementation and management.

In order to test the model, a pilot study was used in a real environmental decision making situation. The model was applied in the design of a green research strategy for a university. The coordinators of the Social Responsibility and Sustainability research theme were first interviewed and then participated together in a focus group, which took about two hours.

The *GRASS* Model aims to help managers to take environmental decisions. This model does not substitute environmental management systems such as ISO 14001 as, while these aim to manage environmental aspects, the *GRASS* Model aims to improve the process of environmental decision making. The *GRASS* Model focus on improving environmental performance through a structured process for environmental decision making. Non-environmental factors (such as customer satisfaction, competitors' actions, image, etc) may also be integrated as key elements for the decision.

It is important that the *GRASS* graphic (in Figure 8.2) has as its core the classic structure of decision making. For example, Hammond, Keeney and Raiffa (1999) identified five elements for smart choices: Problem, objective, alternatives, consequences, and tradeoffs. Kleindorfer (1999) applies decision science to environmental decisions and puts together the phases of problem-solving process based upon formulation of objectives, identification of alternatives, evaluation of alternatives, choice, and legitimacy and implementation. Goodwin and Wright (2004) highlights that decisions can involve multiple objectives, uncertainty, complexity, multiple stakeholders; and so decision analysis should decompose the problem into a set of smaller problems. In a complex context, an understanding of the value and utility of decision criteria is important as is the impact/weight for each criterion (Bana e Costa, 2004; Goodwin and Wright, 2004).

Indeed, such approaches influenced the structure of the GRASS model; however, we have added new activities such as the systems interaction of the elements, evaluation of control level when defining scope, and an analysis of not pursuing an alternative. Alternatives can be ranked on their contribution; but, a different perspective can be gained from considering the implications of NOT doing them.

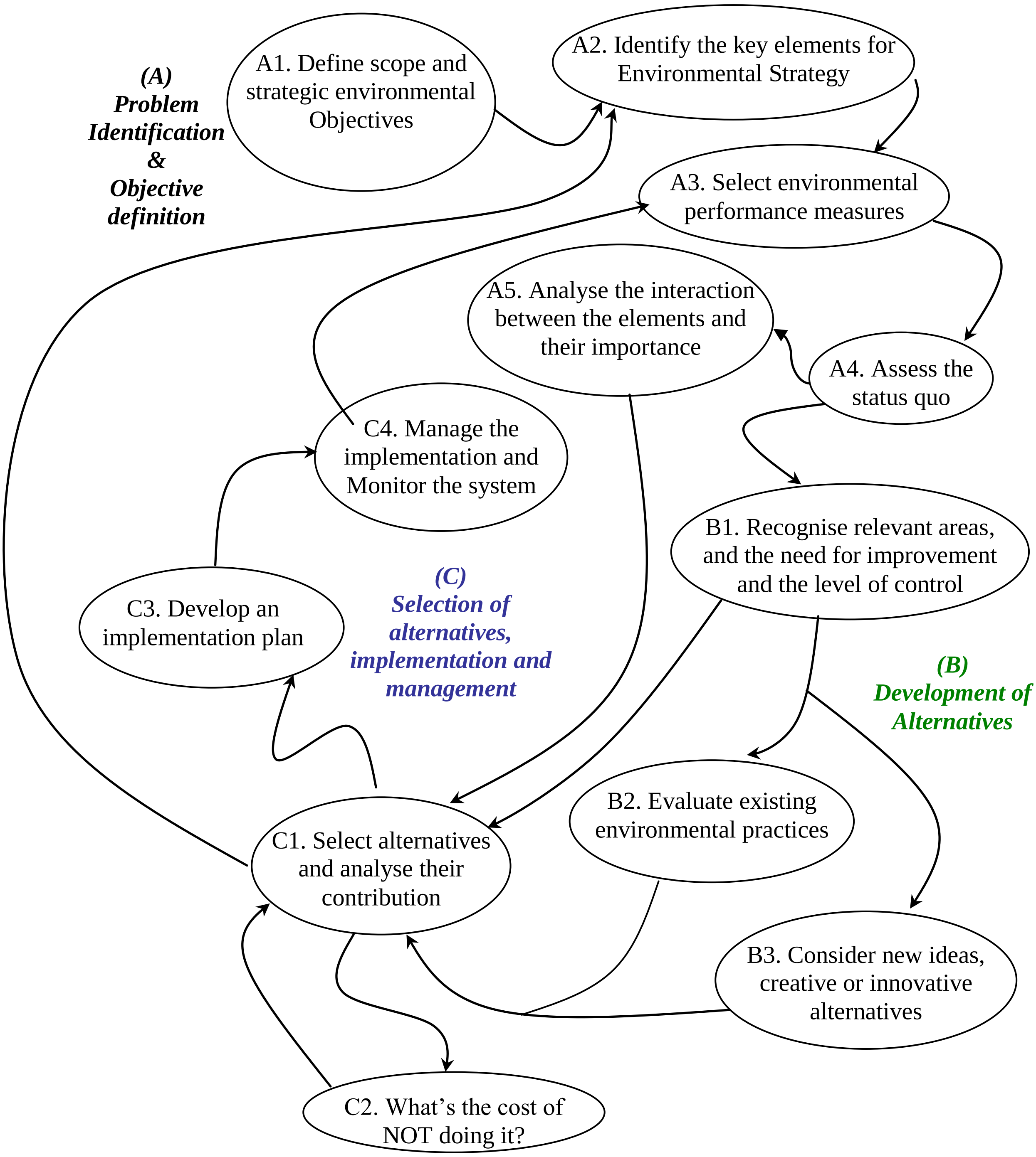

Figure 8.2 – The GRASS Model and its Activities

The next section presents the rationale of the *GRASS* model. It will be followed by the application of the model in a higher-education institution for a real environmental decision making process. This chapter also includes an illustration of the model for greening supply chains based upon the data collected from the interviews. The alternatives shown are also illustrative and are not linked to any of the case organisations albeit they are valid for those companies.

8.6 The *GRASS* model activities and rationale

This section presents the *GRASS* Model, providing the aim and justification of each activity, and its relationship with other activities.

A1. Define strategic environmental objectives and their scope:

Aim: To begin to define the scope of the problem through identification of objectives.

Relationship with other activities: This activity tends to affect all other activities as the starting point of the model. More specifically, the environmental objectives and their scope will impact on the identification of the strategy.

Defining objectives is crucial as they underpin the whole environmental strategy development. Problems' root causes should be identified and resolutions should not be limited to the symptoms of the problems but to its roots (Checkland, 1981; Checkland, 2000; Senge, 1990).

First, it is important to design strategic objectives as directly relating to environmental performance. Objectives should be considered under a broader purpose whilst carefully avoiding the confusion of purpose with the means to achieve the objective. For instance, for many organisations the certification of ISO 14001 is not the final objective but a means to achieving a broader objective e.g. “to improve overall environmental performance”, “to reduce our environmental impacts” or “to become the environmental leader in the sector”. It is essential to clarify if objectives refer to a result or a means to reach this result.

Second, the scope of strategic objectives needs to be defined. In a globalised world, organisations tend to work in different countries with different contexts and environmental demands (English, 1999). Hence, the environmental objectives in a company need to be tailored to its context; and they need to converge towards the improvement of overall environmental performance. Thus a company may share a global environmental strategy while having balanced objectives for its local environment.

A2. Identify the key elements for Environmental Strategy

Aim: To identify elements for designing an environmental strategy.

Relationship with other activities: This activity relates to recognition of the need for improvement. The elements will play a role in the selection of options to achieve an established environmental objective.

We first define what an element for environmental strategy is. We consider an element for the environmental strategy as any issue to be accounted for in environmental strategy development, reflecting reasons for pursuing the environmental objective.

While in the ISO 14001 standard (2004) the environmental aspect and impact assessments are main inputs to define the environmental programmes; in the *GRASS* Model, they are part of a wider range of factors that need to be considered when taking environmental decisions. For example, decisions on supplier selection might be aligned with quality, cost, environmental performance, location and so on. Thus, the structure of the *GRASS* Model simulates how organisations consider environmental initiatives. For instance, Hoffman (1999) looks through the lens of institutional theory at environmental decision making as a corporate issue i.e. impacting on the different functions of a company and its internal organization (marketing, finance, operations, engineering, R&D, etc).

Within the supply chain context, several elements from different views can be taken. For instance, Lee (2004) suggests considering strategic objectives beyond efficiency gains e.g. agility, adaptability, alignment. Taking a systemic approach of feedback loops, environmental initiatives impact on operations objectives (and performance), which could be considered as elements for environmental decision making. Other authors select criteria for decisions based on: human resources, technology, information technology, organization and management, and environmental aspects (Dangayach and Deshmukh, 2001).

A3. Select environmental performance measures

Aim: To select environmental performance measures that evaluate if the organisation is moving towards its environmental objectives.

Relationship with other activities: This impacts on the assessment of the status quo, the selection of options, and the monitoring of the environmental management system.

Once objectives, scope, and the key elements are defined, environmental performance measures can be selected. This may reveal objectives that are hard to measure through conventional quantitative data. Qualitative analysis can help to evaluate the achievements of organisation's environmental strategy. For example, employees may experience increased work satisfaction from reducing toxic substances release. Hence, measures of strategy effectiveness could combine hard data (e.g. the actual percentage of toxic substances) and soft issues that may be hard to capture numerically.

The selection of measures can be informed by various authors who suggest sustainability performance indicators. As mentioned before, Rothenberg et al (2005) suggest an environmental benchmark for automotive manufacturers based on: regulatory compliance, gross emissions, efficiency, and life-cycle analysis. Veleva, Hart, Greiner and Crumbley (2001) list indicators for sustainable production: facility compliance/conformance, facility material use and performance, facility effects, supply chain and product life-cycle and, sustainable systems. ISO 14031:1999 provides examples of approaches for selecting indicators for environmental performance evaluation, which takes measures related to water, energy, material, and other resources consumptions as well as emissions.

A4. Assess the status quo

Aim: To diagnose the company performance before implementing the options. It provides an initial review of how far the company is from meeting its objectives.

Relationship with other activities: This activity is critical to the identification of areas that might need to be prioritised.

Through assessment of the status quo, decision makers can reflect on objectives and identify important areas for improvement. Most companies with an EMS (Environmental Management System) have their environmental auditing system as a source of data to define the levels of current performance. The importance is to evaluate the gap between objectives, goals, and performance.

A5. Analyse the interaction between elements

Aim: To analyse the elements of environmental strategy to identify additional elements and the impact they have on each other.

Relationship with other activities: This activity helps to analyse the contribution of improvement options to achieve the objectives.

Besides linking activities, systems thinking helps us to understand the relationship between elements. For instance, plant location affects how easy a company can meet legislation requirements. Product design can be strongly affected by the availability of materials, and have potential link to suppliers and manufacturing processes, which may be core to environmental performance. Forrester (1961) highlights feedback loops, the magnitude and nature (negative or positive) effects of one element on another when analysing system dynamics. Besides the interaction, elements could be ranked according to their importance to achieve the environmental business strategy.

B1. Recognise relevant areas and the need for improvement

Aim: To reflect the need for improvement and identify key areas to bring the best results. It should help to identify supply chain activities that could be more relevant as well as evaluating the degree of control the organisation has over them.

Relationship with other activities: This activity interacts with the evaluation of existing practices, creation of new ideas and selection of options.

The assessment of the status quo reveals "how much" improvement is needed to achieve environmental objectives and activity B1 identifies areas that contribute to achieving strategic objectives. This activity matches what need to be done with where and how to do it. It identifies important areas in the supply chain, the life-cycle of a product/process, or problematic products/processes of environmental performance. Once areas are defined and the need for improvement is recognised, alternatives can be explored. Being aware of the objectives, key elements, performance measures and how close the company is to achieving its objective, the decision-making team can classify key areas to evaluate, the degree of control the company has over them, and their relevance for the environmental strategy.

B2. Evaluate existing environmental practices

Aim: To benchmark existing solutions and their contribution to environmental performance.

Relationship with other activities: This activity feeds the options matrix for analysing possible solutions.

Potential solutions are benchmarked against the existing environmental practices. Benchmarking could be done against competitors' actions, regulatory guidelines, cross-sector analysis, or internal comparisons across production sites. Considering the uncertainty and complexity around of environmental decisions, it would be important to avoid embarking upon a new practice while less risky, existing practices are available that match the organisation's needs. For instance, a list of practices for operations function could be composed of: green buildings, eco-design, green supply chains, green manufacturing (production), and reverse logistics. Options are evaluated for impact potential (e.g. main barriers, benefits, etc). The innovation of new activities is considered in B3.

B3. Consider new ideas, creative or innovative alternatives

Aim: To consider radical solutions for an organisation to break paradigms and solve problems with innovative solutions.

Relationship with other activities: This activity feeds the options matrix for analysing possible solutions.

Having a systemic and strategic approach, the *GRASS* Model embraces creativity as a source of innovative solutions. By fostering innovation in developing environmental strategy, an organisation might encounter novel benefits e.g. matching higher environmental benefits with a greater profitability and positing itself ahead of legislation and competitors as well as enhancing its value to customers and stakeholders. This may achieve a leap in performance, rather than incremental improvement. For example, one area or process could be approached by radical innovation; while others can continue carrying out incremental improvements.

C1. Select options and analyse their contribution

Aim: To select options that will contribute to an organisation achieving its environmental objectives.

Relationship with other activities: This activity is connected to the elements of environmental strategy, and provides actions that will compose the implementation plan.

The selection of possible solutions can be based on their relation to key elements from activity A2.

By building a matrix between control and relevance, decision makers can visualise elements that are more controllable and relevant for the environmental strategy. Indeed, some of options may radically modify the degree of control of an element in an organisation (e.g. new business models or process reengineering). This should be considered in analysis of its impact on the other elements and the overall strategy. An illustration of an analysis of the activities of the operations function based on the data from case research is shown in Figure 8.3

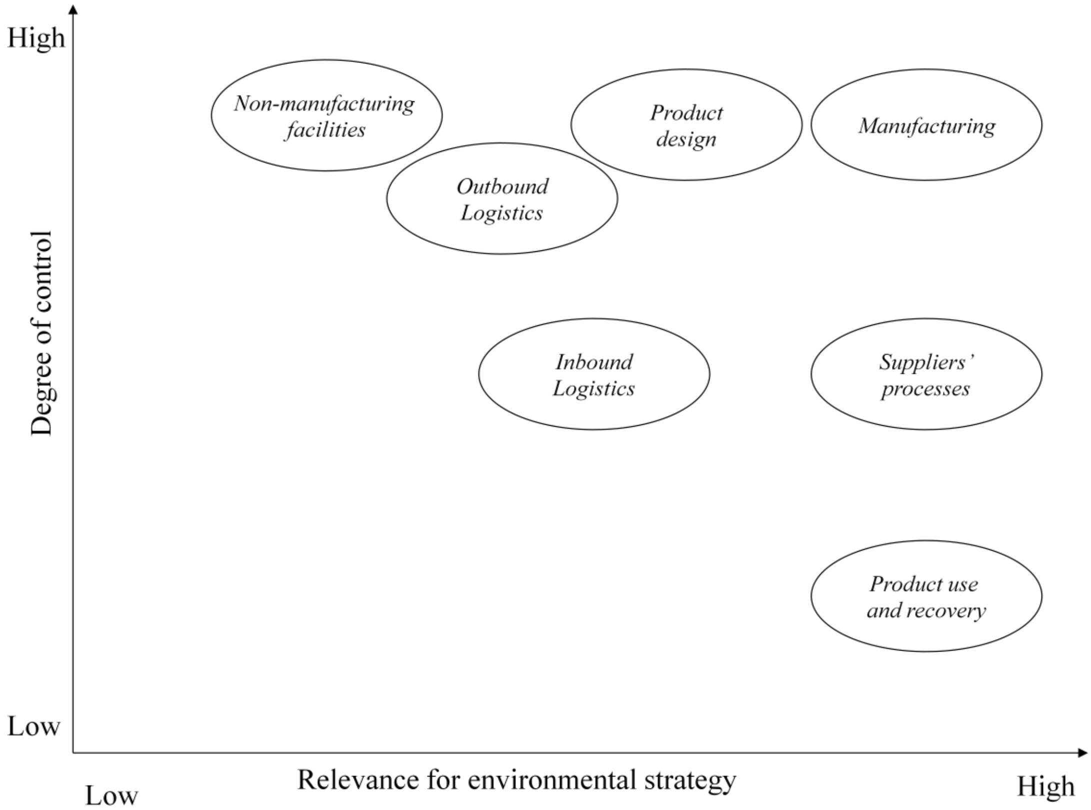

Figure 8.3 – Degree of Control and Relevance for environmental strategy of the activities of the operations function (*Developed by the author based on the findings of case research)*

A table where the rows are options and the columns are the elements of environmental strategy may help to consider the impact of each option on each element. Techniques such as scenario planning could help to identify alternatives to compose the strategic environmental plan. Analytical tools such as Multi-Criteria Decision Making (MCDM) convert qualitative preference judgments into quantitative measures of options, allowing the decision makers to have an analytical comparison of options against elements (Bana e Costa and Chagas, 2004).

C2. What are the strategic implications of NOT doing it?

Aim: To analyse the strategic implications of not implementing an alternative to improve environmental performance.

Relationship with other activities: This activity is part of the analysis of the contributions of selected options for improvement.

Hill (1993) recommends Drucker's concept when designing strategies for manufacturing. Peter Drucker noted that "cost accounting gives you information on the cost of doing, but not on the cost of not doing - which is increasingly the bigger cost" (Hill, 1993). In fact, we suggest that this activity is understood in a broader approach i.e. the strategic implications of not pursuing a higher environmental performance rather than a basic cost opportunity analysis. This strategic debate could bring the dilemma of being an environmental leader or a follower in the market.

Thus, organisations can consider quantitative data and subjective views of issues (e.g market trends, customers' perception, supplier relationship, etc) to estimate the cost of NOT implementing those practices. For instance, the damage to the organisation's image or stock market value may be as important factor as the opportunity cost revealed in a viability analysis. Perceptions of customers, competitors, markets, and the future could be important in designing scenarios and selecting environmental initiatives. This activity was confirmed as important in the case research as some of the companies already use it as part of the environmental decision making process.

C3. Develop an implementation plan

Aim: To formalise the plan for the implementation of environmental improvement actions.

Relationship with other activities: This activity needs to be linked to management and monitoring of the whole environmental management system.

An output of activity C3 is an implementation plan containing actions. Now the choices from C2 can be incorporated in the EMS and be part of its continuous improvement and auditing systems.

C4. Manage and Monitor the implementation of alternatives

Aim: To manage and monitor the implementation of actions. Chosen alternatives are integrated into the routines of the environmental management system. Its importance resides in the learning that will help the company to achieve its objectives. It provides reflection and critical analysis of objectives, performance measures, actions, and implementation.

Relationship with other activities: This activity will focus mostly on the environmental performance measures and its feedback for managing the environmental management system.

Managing and monitoring actions is important for reflective learning and for critical analysis to assess if strategic objectives are being achieved. Activity C4 is not a final step of the *GRASS* Model, but is one where objectives, measures, options and ideas are revisited, aiming for higher levels of environmental sustainability. In fact, having a structured and systematic approach such as the one provided by the ISO

14001 standard will help the company in managing and monitoring strategic decisions in an integrated way. The use of the *GRASS* Model adds a systemic view of how EMS can be structured.

8.7 The *GRASS* Model in Practice

8.7.1 Case profile and the population of the GRASS Model

A business school of a higher-education institution (HEI) operating in the UK intended to green the outputs of its research and teaching activities. The pressures emerged from the top administration and a university-level working group was created. Then, two staff members were invited to lead the greening process of the business school and as a result the Social Responsibility & Sustainability (SR&S) group was created. This group was given the overall objective from the top administration which was to increase the sustainability-related research output as well as the teaching contents. Figure 8.4 shows the inputs, transformation processes, and outputs of the case HEI.

The business school has around four thousand students, 50% of the university students. Currently there is no specific course being offered in the SR&S area and the SR&S research develops in an *ad-hoc* way. The SR&S group is being challenged on taking robust decisions given the limitations of resources in the HEI.

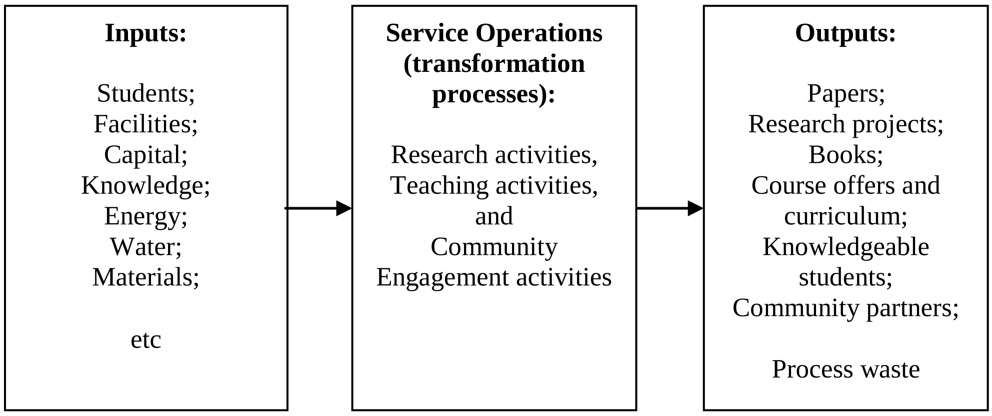

Figure 8.4 – Inputs, transformation processes, and outputs of the HEI.

As the implementation of the actions are still going on, the analysis refers to the contribution of the decision making structure, in which the potential contribution of system thinking in understanding how the elements could impact on each other are critically analysed.

The environmental decisions taken in the population of the model belong to a school and group level (See appendix 7 for the HEI's objectives of environmental strategy). The high-level decisions for internal and external operations, and for the implementation of four of the green operations practices, namely: green buildings, green supply chains, greener processes and reverse logistics are taken at university level; however, the greening of the university products (the outputs of teaching and research) is mostly influenced by the schools and academic groups.

Figure 8.5 shows the *GRASS* model populated for the greening of business school products.

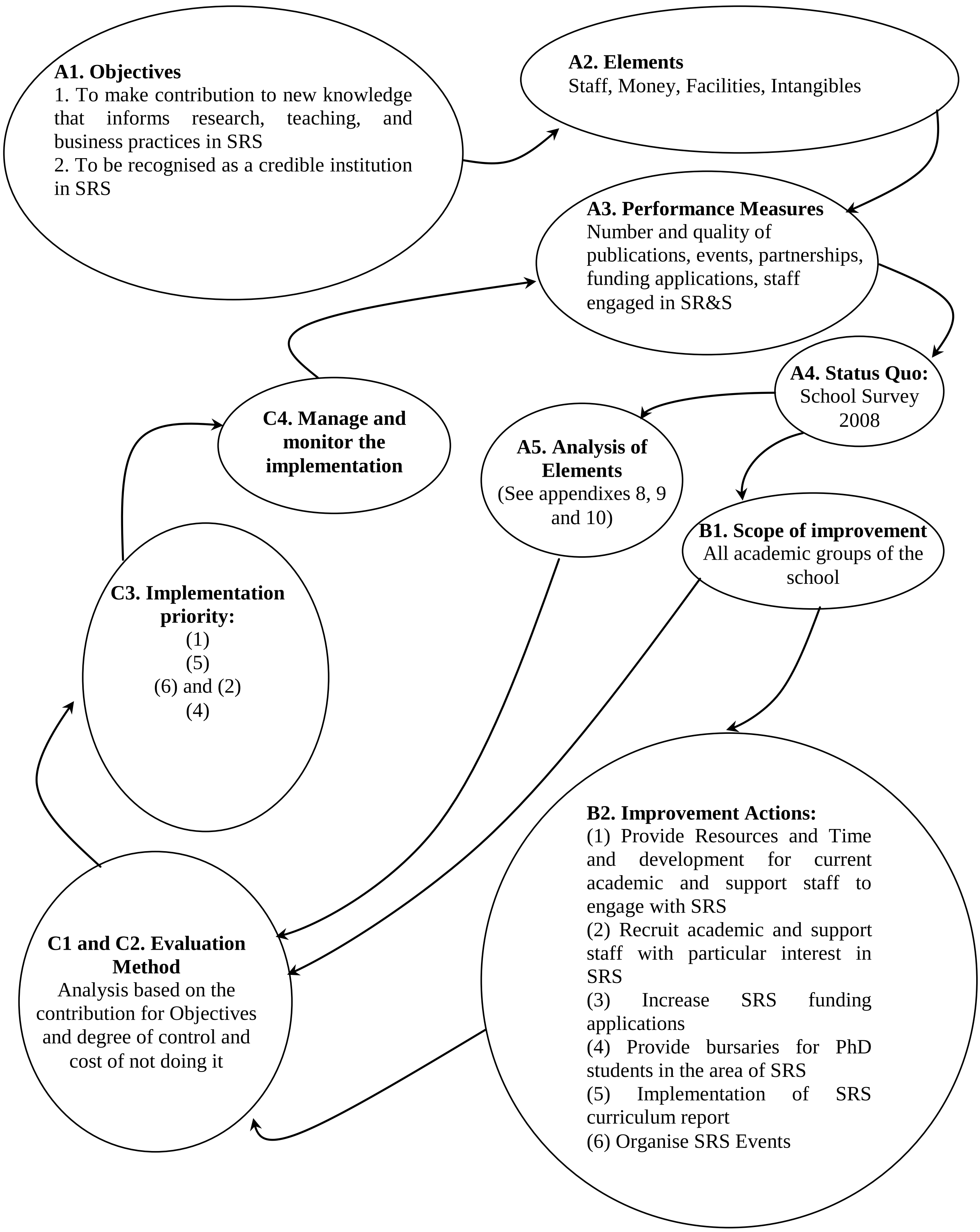

Figure 8.5 – GRASS Model populated model for a Higher-Education Institution

Figure 8.5 illustrate the *GRASS* Model populated for a Higher-Education Institution. The illustration does not include activities A5 and B3, nevertheless, they were part of the decision making conference. Activity A5 has a large textual output that could not aesthetically fit in the model illustration (See appendixes 8, 9 and 10 for the output of activity A5). Activity B3 was performed in conjunction with B2 (See appendix 13 for the whole model output; phase 2 shows the output for B1 and B2). Also, with regard to B3, the participant felt that the existing practices were sufficient as improvement actions and other innovative practices would be considered in the future after the foundations of the SRS programme were built.

As this study focus on the process of decision making rather than the decisions themselves, we consider it more important part of the findings than the perception of the decision making team when using the model.

8.7.2 The Perception of Participants about the GRASS Model

A survey questionnaire was used after the model application in order to receive feedback on our decision making structure. This survey revealed that the participants found that the model helped them 'a lot' in developing the strategy (4 in a 1 to 5 scale).

One participant said: "It helped provide a structured process that then brought my thoughts together". The second participant highlighted the choice of elements: "It made me focus more… really think about the elements involved in developing our strategy".

Both participants found the model only 'a little bit easy' to be used compared to the previous decision approaches they had already used. However, one answered it was somewhat different from previous approaches (s)he had taken, while the other participant found it definitely different. Their opinion about the time of the activity was relatively close (a little bit long and fair). They both said they could use the model again and recommended the model to be used in other departments or for university-level strategy. Also, they found the activity interesting and dynamic, although they complained about its duration.

8.7.3 Data Analysis and critical evaluation of the processes

Objectives

In fact, our data is in accordance with the literature of decision making about the choice of objectives. This was a critical step, mostly to the definition of its scope. The participants were constantly moving back and forth from wider to narrow objectives (strategy only for research or for research and teaching?). Due to the interdependence between these two areas, they moved from an objective that included both research and teaching.

The choice of final objectives was controlled by questioning 'why' until it was possible to move from the means to one final objective.

Elements

There was confusion in the beginning of this activity between elements and actions (options). They also discuss quite extensively the wording, and therefore, the sub-elements for environmental strategy. For instance, for STAFF, they chose to split it down to academic and support staff.

Measures

While choosing the measures, the participants were worried in having quantitative and qualitative measures. Another concern was related to the choice of measures difficult to be measured. Besides quantitative and qualitative, the measures they selected included both measures for final result and efforts (intermediate results).

Classifying the elements

When classifying the elements based upon a matrix of degree of control and relevance to environmental objectives (see appendixes 8 and 9 for the output of activity A5), the matter of “who really controls” was raised, i.e., they were developing the strategy; however, they were not in control of some of the elements (such staff members – to be hired through the school budget). Also, the fact of an element being external or internal to the organisation was mentioned.

During this classification activity, the decision makers were asked to rank the elements in a hierarchical order aiming at a deeper thinking of the elements’ weight.

Selecting improvement actions

The actions were relatively easily listed. They mentioned the fact that the structure gave more consistency for the decisions as well as the importance of the visibility of the objectives to form the improvement actions. In fact, at one time of the activity, one participant highlighted the team was forgetting about part of one objective (teaching) and only focusing on research.

Analysis of the contribution of the actions to the objectives

Similar to the classification of the elements, this activity needed the stimulus of the facilitator in provoking reflection to create a priority order. For time constraints, it was not possible to analyse the effect of the actions on the elements.

8.7.4 Potential contribution from systems thinking theory

The decision making team chose four elements: Staff, Money, Facilities, Intangibles. Due to the time constraints, there was no evaluation of the relationship amongst the elements. Nevertheless, we can see the potential contribution of systems thinking through a deduction analysis (See appendix 10). Some examples below:

- the SRS staff can affect money negatively by increasing the costs in salaries
- the SRS staff can affect money positively by attracting money through research grants
- Money can affect staff positively by offering good salaries

- Money can affect intangibles positively by funding partnerships with other institutions
- Facilities can affect money negatively by construction and maintenance
- Facilities can affect money positively by profitable activities
- Partnerships can affect staff positively by enhancing the academic networking

A more systemic view of the elements could help the decision makers in minimising the problems of lack of control with a specific element or the apparent low relevance of one element that in fact has strong effect on other relevant elements.

8.7.5 Reflection on the GRASS Methodology

This section reflects on the value of the model to practice, the lessons learnt from its first applications in a higher educational institution, and its limitations.

Value for practice

Intuition and experience as a decision making method are vulnerable to imperceptible factors (Tversky and Kahneman, 1981), that can be worsened when decision makers do not hold expertise in the field they need to make a decision (Kahneman and Klein, 2004).

The *GRASS* model is not required where responding to clear demands such as certification, legislation, continuous improvement programmes, and it may be unnecessary to go through a time consuming process as suggested here. However, the

GRASS model will be more useful for companies that need to think strategically, particularly when initiatives are less well defined, have stronger trade-offs, limited resources, and need prioritising several alternatives. Here the model can help in taking more consistent decisions as well as better understanding the strategic implications behind environmental initiatives.

Lessons from the model application at a UK University

During the focus group, the participants stressed the main benefits of the model included: "It helped provide a structured process that then brought my thoughts together". On the choice of elements: "It made me focus more… I really think about the elements involved in developing our strategy". However, problems regarding time and the difficulties in accomplishing some of the model activities have also been cited in the participants' feedback: "Time is an issue, but I am not sure how this can be resolved, as it appeared necessary" and "It was painful at times; but absolutely necessary".

Defining the environmental objective can take time but it is important not to rush into initiatives before thinking of the core purpose of the environmental strategy. A concern with wording the elements also might take time as participants merge and split the elements to identify key elements (avoiding a long list of criteria). This is subjective and depends on the problem; however, four to eight key elements might begin the analysis, with more being added or deleted, if required.

In choosing environmental measures, participants found it hard to include intangible measures which are hard to measure; nevertheless, they said it was important to have a balance between quantitative and qualitative data for performance measurement.

The role of the facilitator was thought to be important for some activities (e.g. A5. Analysis of the interaction of elements) where they could guide the level of detail that could be reached by observing the impact of the elements. According to one participant: “It is easier to think of the broader picture than to think what this means individually and what the outcome will be”. The main issues related to selecting alternatives were related to the consideration of their impact on objectives, elements and improvement on the measures to justify the alternative. .On ranking alternatives, participants said they could “guess” the results before doing it; however, they felt more confident and reassured to have an audit trail that confirmed their predictions.

The methodology was considered important in building a justification for environmental initiatives and positioning environmental issues in the organisations’ political agendas. Hence, the *GRASS* model can be a tool for top administrators and middle managers who negotiate the importance of environmental initiatives. This was particularly linked to the activity ‘the strategic implication of NOT doing’, because participants highlighted: “The positive effects of doing and negative effects of not doing are not the same thing” and “it is for the people who do not want to take the actions” (see appendix 12).

8.7.6 Limitations of the model

As with most decision support tools, a limitation of the outcome can result from the model depending on information the decision makers have when undertaking the analysis. Because it is not a prescriptive approach, a successful use of the methodology may need expert input however, companies may face problems in the availability or access to technical information. Thus it is important to have the 'right' people involved. The model requires the decision makers to identify the main drivers, areas involved and the implications of the decision for the organisation. However, in practice due to political differences and time constraints, it is not always possible to have the right people together in the same room at the same time.

The table of results from the focus group is shown in appendix 13.

8.7.7 Future development and use of the GRASS Model

The *GRASS* model is being revised after its application in a Higher-Education institution. The lessons learnt from its first application, in conjunction with the findings from case research, will be incorporated for future applications. From its application in a focus group, the issue of most concern is the fact that a facilitator is required and it is a time consuming activity. The case research also suggested that it may be difficult to join personnel from different areas for decision making meetings, specially, when agility is required in the decision making process. There are possibilities of applying it to automotive companies, other manufacturing organisations, and for public policy on sustainable mobility.

JMC has demonstrated interest in using the *GRASS* model for its green supply chain decisions. Waltham had also had the intention of using it for a real environmental decision; but during the financial crisis the company gave up due to cost cutting reasons. In public policy, the field of sustainable mobility provides enough richness and complexity for the use of the *GRASS* model.

8.8 Chapter Summary

Chapter 8 presents the Green Operations Framework and the *GRASS* model. The Green Operations Framework was developed based on the literature and aimed at strategic environmental decisions at company level. Despite being theoretically sound, the framework characteristics created problems to test and evaluate its effectiveness in dealing with real environmental decision making. With the input of systems thinking methodology, in particular soft-systems methodology, the *GRASS* model was created with more research flexibility. As a result the *GRASS* model was chosen to be applied in practice instead of the Green Operations Framework. This chapter also presented the activities and rationale behind the *GRASS* model emphasising the aims of each activity and its relationship with the other activities of the model.

The *GRASS* model was chosen to be populated, tested and evaluated in a real decision making situation on greening the research and teaching outputs of a business school in UK. The perceptions about the model were related to the enhancement of robustness of the decision making processes specially when dealing with complex problems.

Chapter 9 - Conclusions

This Chapter first presents the main conclusions of the research. With particular focus on the automotive industry, the importance of environmental decision making is then discussed followed by the limitations of this research investigation. As far as the limitations are concerned, the contributions to theory and practice are presented. This Chapter end with discussion of opportunities for future research and a section about the reflective learning and an assessment of the achieved objectives.

9.1 Main conclusions

There are three main aspects of the thesis from where these conclusions are drawn: (1) environmental reports of automotive companies (content analysis); (2) case study research (personal interviews and focus group); and finally, (3) the *GRASS* model application through focus group activities.

From the environmental reports, it can be concluded that although there are significant similarities in the environmental practices adopted by major automotive groups, the context of where they operate still plays an important role. Global companies operating in different markets will face different drivers for implementation of environmental initiatives. These drivers may influence the order of priority in which environmental practices are implemented. Similarly, external conditions will influence the complete diffusion of greening practices, their actual performance for the operations function, and ultimately, their value for the overall strategy.

The case study research, from a qualitative primary data analysis, allowed investigating in more detail the reasons why and how the companies go green. There were more in-depth insights due to the nature and characteristics of the data collected. With regard to the drivers, it is evident that one driver can have an impact on other drivers. This is an issue that may be further investigated, perhaps through quantitative research methods. In addition to that, and generally speaking, there is a poor understanding of environmental strategy. Very little on the formulation, implementation and monitoring of environmental strategy was actually found across the case analyses. Similarly, environmental policy is not well understood in the business context, poorly translated into strategy and eventually into tactical and operational actions.

Nevertheless, when the internal policy is the main driver, difficulties may be reduced and implementation of environmental initiatives may become easier due to the political and financial support from the top administration. Paradoxically, companies with a good understanding of environmental policy and its translation into strategy, penetrate in a zone of complexity and uncertainty regarding the benefits of cutting-edge environmental practices, especially, related to non-manufacturing activities and product-oriented green initiatives.

It could be concluded that environmental competition is still in its early stages, and this is perhaps due to the lack of clarity on what are the competition criteria that defines what is green and what is not green, both in a given industry and across different industrial sectors. In fact, the lack of environmental strategy may be a consequence of the lack of competition. Where competition is visible, the perceived value of strategy is higher.

In the hope of helping companies that need to take strategic decisions towards higher levels of environmental sustainability, the *GRASS* model appears as a proposed approach. This constitutes another contribution of this thesis. The model itself seeks at enhancing the robustness and consistency of the environmental decision making process.

9.2 Rethinking the Automotive Industry: the importance of environmental decision making

Being the chief objective of this PhD study, there are specific conclusions that need to be made to the automotive industry. The sustainability and survival of automotive companies will ultimately reside in their environmental decisions. An exciting era for the automotive industry is coming in the next few years, which can change the current rules of competition. Expertise on technological areas such as telematics, alternative fuels, and material engineering will be required to produce 'the cars of the future'. However, these are not necessarily present as the core competences of most car manufacturers, nowadays since most of R&D efforts have been historically linked to power and speed of internal combustion engines, extensive use of all-steel body

Although there is a wide range of environmental practices being used by car manufacturers as shown in Chapter 4, the fundamentals of the automobile as a product has been unchangeable: internal combustion engines, all-steel body, and multi-purpose design. The production processes have historically had, although relevant, little change in more than 100 years since Henry Ford designed and implemented the assembly lines to mass produce the Ford model T. The philosophy by which cars are produced and used today is not much different from Ford's since 1908.

In the beginning of this decade, the challenges for the automotive industry are enormous in both product and production processes. After being strongly affected by the financial crisis, the recovery of car manufacturers is simultaneous to the introduction of electric models in the market. On the product side, considerable uncertainty remains around their choice for electricity to power their vehicles. For instance, Bill Ford, the great-grandson of Henry Ford, who serves as the executive chairman of Ford Motor Company, makes the complexity and uncertainty around product development and powertrains technology explicit. He gave an interview for McKinsey, which was published in January 2010. When asked on what would be the right way (technology) for the future, he answered:

> ***McKinsey Quarterly:*** *With so many different paths out there—improved internal combustion engines, electric cars, biofuels, hydrogen—what is the right way to manage the uncertainty? Do you have a gut feeling which way this might break?*
>
> ***Bill Ford:*** *(...) Sitting here today, I'd say electric. But if we were having this discussion 18 months ago, I would have said biofuels. If we'd had a conversation 18 months before that, I would have said hydrogen. So things are changing really quickly. There is always a technology darling of the moment. We just need to make sure that we're not only abreast of all these technologies but trying to lead in all of them—and also staying abreast of developing technologies. I don't want to be at the end of the pipeline, where we're the last ones figuring things out. Today, electric and plug-ins clearly look to be the most interesting play. We need to be nimble enough so that, 18 months from now, if something else is the most interesting play, we can roll with that (McKinsey, 2010, p8).*

Although the financial crisis had broken the momentum of environmental investments, the "Ecological Tipping Point" is near. The Ecological Tipping Point is defined by the author *as the convergence of essential factors to make an environmental innovation to happen*. The Ecological Tipping Point will happen soon because of the alignment of various important factors that are pushing the industry for a transformation, namely: public pressure, political debate, economic incentives, green venture capitalists, emergence of green competition, scarcity of material, energy and water, and finally, technological feasibility and viability. Companies will need to be prepared to seize upon the ecological revolution that the Ecological Tipping Point will bring, otherwise, they may not be in business tomorrow. This is valid particularly to car manufacturers, but not exclusively. The transformation required may be as large as it was conducted by Henry Ford and Taiichi Ohno; but this time it will need to go beyond process and meet sustainability requirements of the product. This may include rethinking business models, relationships with customers, and the entire vehicle life cycle.

The challenges of investing in such fast-changing technologies will require a higher degree of flexibility from the automotive industry that is not evident in current production structures of large manufacturing plants and mass-standardised products. Besides, the pursuit of economies of scale has led car manufacturers to extend their production networks worldwide making production far more complex. Today, they face largely complicated decisions with regard to whether one single global solution is better than various regional or local solutions in order to green both the product and production processes.

9.3 Limitations

In this thesis, conclusions were drawn from the research investigation in five different industries: automotive, textile (carpets and garments), food processing, chemicals, and higher education. These traditional industries may not reflect the same context and reality for environmental decision making of new fast-changing manufacturing industries such as electronics, nano and biotech, and the like. Similarly, this is an investigation of manufacturing firms, which although includes a number of non-manufacturing activities may not be generalised to service companies (telecommunication, tourism, construction, etc) completely. Service operations could have different paths in greening their activities as well as the influence of the same drivers. The decision making process in service organisations could differ from manufacturing due to the level of interaction with customers, level of intangibility of the product, and other characteristics of service operations. Hence, these are the first set of limitations that we should highlight in the research.

Secondly, the investigation included companies operating in four different countries (USA, UK, Thailand, and Germany) and belonging to five different brand nationalities (British, German, French, Thai, and Japanese). However, as it was found that different national environments, cultures and political systems will make companies look at environmental decisions differently, the decisions themselves may not be generalised. Companies should be careful in taking the decisions by the case companies as 'best practices'. Ideally, one should first analyse the strength of drivers, availability of resources, infrastructure, the development of research and technology, before taking an environmental decision as suggested by the *GRASS* model as the elements of environmental strategy.

This leads to the third possible limitation of the results that is strongly related to industry and location. For instance, most companies in this investigation did not belong to industrial clusters and the decisions dealt with main stream technologies of these traditional industrial segments. It is known that industrial clusters can influence the dynamics and capabilities in managing the companies' operations (Porter, 1998). Environmental decision making may also change according to the type of technology, and the behaviour of companies in taking decisions may not follow the steps as presented here. For instance, it was not discussed in detail issues of companies leapfrogging the decision making stages from manufacturing to non-manufacturing, without major problems in dealing with the complexity of environmental decision making. In short, aware of this limitation, the generalisability of the results is aimed at the process of environmental decision making, rather than the environmental decision themselves.

In addition to the research results, it is necessary to comment on the methodological limitations of this investigation. For the environmental report analysis, the documents carry self-declaration on environmental initiatives. An evidence-based method would be necessary to verify whether all information in the reports is representing the truth.

With regard to the case research, the choice of a multiple case study approach provided more breadth indeed. However, it was at the expense of a deeper investigation in each case. Ideally, more time with each company would have provided a better understanding of the environmental decision making process within the various organisational levels (strategic, tactical, and operations); but as the 'big picture' became more important and due to the accessibility, a larger scope was followed enabling a cross-sectoral approach as well as providing the breadth necessary to build up the theories presented at a higher level of generalisibility. Nonetheless, when this multiple case approach was taken, the limited time and access forced the investigation to choice data collection with "key informants", which constitutes the major limitation of the data collection method. Personnel from different organisational functions may have different views of the environmental initiatives, their drivers, the nature of decision making processes, and other subjective issues included in the semi-structure questionnaire. Other factual issues such as the origin of ideas and decision making structures are less vulnerable to this limitation; mainly, when triangulation was possible to check internal and external documents about the environmental decision.

Limitations could have also occurred in data analysis techniques. The environmental report analysis was less vulnerable to errors in the data analysis due to the nature of content analysis in both print and electronic document. In the case analysis; nevertheless, errors that are embedded in any inductive-deductive reason process could have happened in the process of interpreting the data, specially, for the cases where the interview could not be audio recorded or where both the researcher and the interviewees may have missed an important part of data in the reports. In defence; however, the necessary actions were taken to minimise the likelihood of this happening since in some of the cases it was possible to review the documents, keep in contact with interviewees by e-mail, phone, or arrange a second interview, in which the findings was revised.

9.4 Theoretical Contributions

The originality of this thesis resides in its different angle and breadth of analysis for environmental decision making in manufacturing organisations. It contributes to the field of Operations and Technology Management through a better understanding of the multiple objectives green initiatives may have to meet beyond the improvement of actual environmental performance.

The first theoretical contribution is related to the categorisation of Green Operations Practices. By identifying different characteristics of environmental decisions related to each broad activity of operations function, a new structure opens for environmental benchmarking.

The second contribution to theory is a significant progress to the existing understanding of environmental strategy and decision making. In the past 15 years, several studies, both qualitative and quantitative, have been advancing the environmental management field into a more mature stage where robust theories can start to emerge. In its early stages, for instance, the debate was triggered by the impact of environmental technologies on firm performance. Theoretical studies in management deducted that firms would migrate from pollution control to pollution prevention and by so doing, their investments on green technologies would have a positive impact on operations and financial performance (Hart, 1995; Klassen and Whybark, 1999a; Klassen and Whybark, 1999b). Investments in end-of-life technologies were now differentiated from pollution prevention investments. Although the apparent progress, a dichotomy still existed in the early 2000s with regard to environmental initiatives: win-win solutions were not always possible for pollution prevention investments (Orsato, 2000).

The strategic nature of environmental management became evident and the link between drivers and environmental practices and performance continue being discussed. This PhD thesis contributes to this latest thinking. Green Operations is indeed largely strategic and its benefits need to be evaluated beyond actual environmental performance improvement, and possible cost reduction opportunities. An ‘environmental’ learning and innovation will be critical for companies to compete in the future and this thesis shows how companies can benefit by strategically implementing a green agenda, or lose their position by neglecting it.

Perhaps the most important theoretical contribution is the empirical evidence on why companies concentrate their initiatives to manufacturing processes and delay product-oriented ideas. Those that can develop the ability to deal with risky context and identify a way of accommodating product environmental interventions profitably may transform green leadership into business competitiveness – in a similar manner of what happened in the 1980s with the quality management systems.

9.5 Practical Contributions

A number of practical implications can be derived from this thesis. This PhD research project has investigated companies in different stages of environmental leadership, and with different decision making experience. The results will be useful for both beginners when implementing environmental initiatives and also experienced teams when facing new decision-making situations.

The dynamic nature on how drivers are linked to environmental initiatives is another contribution. Companies can take the lessons of the automotive industry and prepare themselves for pressures beyond legislation, and of course, act accordingly.

The *GRASS* Model should also be considered a contribution to practice. It can serve as a guide to a holistic view of environmental strategy and its systems thinking features can help companies to develop robust plans and avoid the implementation of practices with little strategic value.

Finally, the ‘stories’ of the companies documented here can have a practical contribution since early-adopters can learn from others’ experiences and advance quicker in their environmental learning curve.

9.6 Opportunities for future research

The limitations of this study leave several opportunities for future research. These opportunities reside in two main possibilities: (1) extending the sustainability scope; (2) applying different research methodologies.

9.6.1 Extending the sustainability scope

This study on green operations was function-based (i.e. considering solely the operations function) due to several feasibility issues such as cost and time. A long, and likely more expensive, research project can provide an important extension of the sustainability issues beyond operations by considering the context of where the company operates and sell their goods and services. For instance, the author has submitted a research project on an urban mobility study of four European regions that can bring insights on the introduction of electric cars. The results can perhaps impact on the perceptions of car manufacturers on how to produce, market and monitor more sustainable vehicles.

Another example is related to the importance of location in influencing the environmental decisions for operations. Ecologically-sensitive locations may have different characteristics that can attract or impede the development of more sustainable businesses.

Finally, the topic of sustainability, especially the issues related to green operations, needs to be advanced from a theoretical perspective. There is still a struggle to understand properly what sustainable businesses are and their ability of creating economic growth and development.

9.6.2 Applying different research methodologies

This thesis used a multiple case study research methodology. It indeed provided enough breadth and depth to understand the environmental decision making processes within manufacturing organisations. It also applied the *GRASS* model to pursue further insights in the decision making processes.

More can be achieved by using the results from this study and the issues raised in this research in order to develop new research questions that can be investigated further using different research methodologies.

For example, a longitudinal case study can be conducted to go deeper in to how companies respond to emerging environmental demands triggered by external and internal drivers, in particular those towards product-oriented decisions, where this research has found it to be more complex and riskier.

As the field becomes more mature and the concepts are established across different disciplines, the use of quantitative methods will be imperative in order to help decision and policy makers. Quantitative research can help answer a number of questions related to important issues raised here such as the impact of one driver upon another for environmental decision making; the level of moderation and mediations in the relationship between drivers, internal policy, and implementation; the importance and relationship of green operations practices according to industry location and sector, as well as size and age of organisations.

In addition to qualitative and quantitative methodology, other novel research approaches such as action research could be used. In this research, the *GRASS* model was only applied to a higher education institution. An application of the model through action research in other organisations such as those from manufacturing and agribusiness sectors could bring more insights to the decision making processes. Within manufacturing, the comparison between manufacturing activities would be particularly useful. Using the model to build a sustainable manufacturing strategy and take decisions can also expose the model to a higher level of complexity that would bring relevant contributions to the field.

9.7 Chapter Summary

Chapter 9 presented the main conclusions of this PhD investigation. A section was dedicated to rethinking the automotive industry once this industry was the main sector in the research.

It became clear how the context can play an important role when designing the environmental operations strategy of a company. This was noticed in environmental reports, and through the interviews and focus groups carried out in both automotive and non-automotive companies. The differences in drivers and complexity for greening manufacturing and non-manufacturing activities within the operations function are also part of the PhD conclusions.

These issues are of high relevance for the automotive industry, which is now suffering with the increasing demands to green its products amidst the high uncertainty, complexity and risk of doing it. In fact, many are realising that the ‘cost of not doing’ can be higher in the long-term, so there are a number of initiatives to green companies beyond manufacturing activities.

Certainly, the results and conclusions of this PhD thesis are not without limitations, which were discussed in the section 9.3. The final sections of this chapter focus on the contributions of this study and the opportunity for future research.

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Appendixes

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Appendix 1 – Research Cover Letter

Aston University

Breno Nunes & Professor David Bennett
Aston Business School
This research is supported by the EC Alβan Programme.

Green Operations in the Automotive Industry

We are grateful for your interest in assisting us in this research project. This document offers a brief overview of the project, its aims, benefits, and a proposed schedule. Participation in this project is voluntary and participants are able to withdraw the research at any time.

Objective of the project

This PhD research project is aimed at developing a green operations model, which seeks to improve environmental decisions in the automotive industry. It is supported by the European Commisions's Alβan Programme.

Description of the project

This research project is being conducted by Breno Nunes under the supervision of Professor David Bennett in the Technology and Operations Management Research Group at Aston Business School.

The motivation for this research comes from the economic and environmental problems that automakers are currently facing. The industry suffers from overcapacity, and is struggling with low profit margins, high break-even points, and undergoing increasing pressure to reduce its environmental burdens. Most of these pressures relate to the consumption of fossil fuels and the consequent engine gas emissions during the car use, intensive use of natural resources of the manufacturing processes, production plant emissions, final disposal of cars, and also, traffic congestion and road accidents. Thus, these economic and environmental problems bring huge complexity for the strategic decisions within the operations function. Furthermore, the automotive industry is one of sectors that employs most people; therefore, there are relevant reasons to conduce scientific research to ensure that better environmental decisions are taken within this industry.

The empirical research design in this project is composed of three major activities: (a) overview and analysis of environmental initiatives in the company, (b) personal interviews, and (c) a focus group for the development of the model. In order to accomplish these activities, we consider that one day will be sufficient for activity (a), each personal interview will take no more than one hour, and finally, the focus group activity will probably need 2 hours.

Research questions

Our research comprises four research questions:

1. Why and how do automotive companies take environmental decisions?
2. Where do (environmental) ideas come from in the automotive industry?
3. How do automotive companies measure their environmental performance?
4. How does a "Green Operations" model contribute to the improvement of environmental decisions in automotive companies?

Benefits for the company

Your company will benefit from leading the development of this green operations model and, furthermore, will participate in a project aiming at increasing cooperative learning on sustainability for car automakers. Other benefits are: process improvement through the application of the model, prioritisation of environmental technologies or solutions and the opportunity to generate awareness of your environmental initiatives in our publications.

Ethical and confidentiality issues

We should stress that our project follows the research ethical code of confidentiality and before we publish any of the findings relating to your company we will first seek your approval.

Proposed Schedule

We are flexible and will work around your availability for the proposed activities. Our suggested plan is to start our data collection for activity (a), overview and analysis of environmental initiatives, during February, 2008. We will ask you to confirm if this period is adequate for you.

We look forward to hearing from you at your early convenience.

Sincerely yours,

Aston University

Information on this page has been removed for data protection purposes

Breno Nunes
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Appendix 2 – Empirical Research Design

Green Operations in the Automobile Industry
Breno Nunes & Professor David Bennett
Aston Business School
This research is sponsored by Alban Programme Scholarship Nº E06D103633BR.

Empirical Research Design

This document explains the empirical research design of the project. It presents the methods that will be used to answer each research question and the purpose of each phase of the empirical research.

Research Questions:

1. Why and how are automakers taking environmental decisions?
2. Where do (environmental) solutions come from?
3. How do automotive companies measure their environmental performance?
4. How does the *Grass* model contribute to the improvement of environmental decision making in the automotive industry?

The above research questions will be answered using primarily 4 methods: personal interviews, focus group, secondary data, and survey. These methods will be used across the empirical research phases described below.

The unit of analysis for this research is decision making teams.

Phases	Main Purpose	Methods and instruments employed
I. Diagnosis of environmental practices, initiatives, understanding of the drivers for environmental decision making This phase is aimed at descriptive analysis, case evaluation, identification of key informants, collection of reports, etc.	Explore environmental initiatives in the company	Personal interviews, Secondary data collection.
II. Personal interviews. This phase includes the selection of participants the focus group activity. It also initiates the identification of key elements of environmental strategy (from an individual perception), performance measures used by the company, origins of ideas, current environmental performance It should also provide access to more secondary data, and evidence of the process of decision making.	To identify of participants the focus group activity. Identification of decisions drivers, elements, performance measurements in order to ease the population of the model	Personal interviews (through a semi structure questionnaire) Secondary data collection
III. Application of the environmental decision making model	To populate and evaluate the GRASS model	Focus Group (for model population) Survey (for model evaluation) Voice recorder

Appendix 3 – Semi-structure questionnaire for personal interviews

Introduction and Interviewee profile

Can we start with a brief introduction about you?
How long have you been in this company?
What is your role and responsibilities here?

Could you please tell me about the environmental or sustainable initiatives in your company?

RQ1 Why and how – company level
Tell me the reasons and main drivers behind those initiatives.

Could you please describe how the importance of environmental issues in your company has evolved over time?

RQ4 Use of environmental decision making structures
What environmental decisions do you recall in this company?

Have you participated in any environmental decision making team in your company or department?

Regarding the decision making process, could you explain how the decisions were taken?

If you could have a model to help you and your company in taking environmental decisions, what would be the core elements of this model? *(prompt: For instance, What do you expect from this model? Outcomes, characteristics, etc)*

RQ3 Environmental performance – individual level
If you could define a green car company, what would be its main characteristics?

If you could define a green automobile, what would be its main characteristics?

RQ3 Environmental performance – company and department levels
How do you measure environmental performance in your company?

Do you have any specific environmental performance measures for different organization levels? (units, departments, global, or even projects)

RQ2 Where do solutions come from?
When you think of the initiatives that have been implemented in your company, where did those ideas come from?

Appendix 4 – Focus group protocol for the *GRASS* Model application

Focus Group

Model application

Populating the model through a focus group activity

Focus group structure:

i. Understanding the focus group: objective, 10 min
ii. Defining an environmental objective and scope
iii. Listing the elements of the Environmental strategy;
iv. Identifying the key elements for the Environmental Strategy;
v. Selecting environmental performance measures
vi. Reflecting about the status quo – include gap analysis
vii. Classifying the elements of environmental strategy (relevance x control)
viii. Looking at interaction between the elements
ix. Development of alternatives
x. Selection of alternatives

Evaluating the model

The model will be evaluated through a reflective section during the focus group and a survey questionnaire in the end of the whole activity.

Appendix 5 – Survey Questionnaire for the *GRASS* Model Evaluation

Aston Business School
Model Evaluation Form

For appropriate questions, please circle the number which best reflects your opinion.

About the model

1. How did this model help you in taking environmental decisions?

Not at all	A little bit	It helped me in somewhat	It helped me a lot	Very much
1	2	3	4	5

Please provide some comments to justify your answer:

2. How different is the model from previous approaches you have taken?

Not at all	A little bit	Somewhat different	Definitely different	Very different
1	2	3	4	5

3. How important was the task of looking at the interaction of the environmental strategy elements for the final decision?

Not at all	A little bit	Somewhat important	Definitely important	Very important
1	2	3	4	5

Why?

4. How easy was the model to use?

Not at all	A little bit	Somewhat easy	Definitely easy	Very easy
1	2	3	4	5

5. What is your opinion about the time the activity took?

Too long	A little bit long	Fair	Short	Too short
1	2	3	4	5

6. Would you be able to apply the model yourself in your organisation for other decision?

No chance!	Perhaps, not. I do not feel comfortable	Perhaps, yes. I feel somewhat confident.	Yes, I would do it	Yes. I feel very confident
1	2	3	4	5

7. Willingness to use it again – Would you be interested in running the model again?

No chance!	Perhaps, not.	Perhaps, yes.	Yes, I would be interested	Yes, I would be very interested.
1	2	3	4	5

8. Applicability of the model– Do you think this model would be useful for other departments in your organisation?

No!	Perhaps not.	Perhaps yes.	Definitely, Yes	Yes, very much..
1	2	3	4	5

Please provide some comments about how we can improve the model

____

____

____

____

____

About the facilitator

9. Did the facilitator stick to his role?

Not at all	A little bit	He did somewhat	Yes, he did.	Yes, he definitely did
1	2	3	4	5

10. Was the facilitator effective in guiding the application of the model?

Not at all	A little bit	He was somewhat	Yes, he was.	Yes, he definitely was
1	2	3	4	5

Please provide some comments about how the facilitator can improve his/her performance

____

____

____

____

About the workshop

11. Was the workshop run in an appropriate venue?

Not at all	A little bit	It was somewhat	Yes, it was	Yes, it definitely was
1	2	3	4	5

Please rate the workshop according to the following points

12. Was it a dynamic and an interesting experience?

Not at all	A little bit	It was somewhat	Yes, it was	Yes, it definitely was
1	2	3	4	5

13. Did everyone have the chance of having their say?

Not at all	A little bit	Yes, somewhat	Yes, everyone was able to express his/her ideas	Definitely Yes.
1	2	3	4	5

14. Would it be good to have a similar workshop to design your company's environmental strategy?

Not at all	A little bit	In somewhat, yes	It would be interesting	Definitely Yes.
1	2	3	4	5

15. Would you recommend this workshop for other departments or environmental decision making teams at your company?

Never	No, I would not.	Perhaps I would	Yes, I would	Definitel y Yes.
1	2	3	4	5

Please provide some comments about how we can improve the workshop

Appendix 6 – Interviewees' Consent Letter

Breno Nunes & Professor David Bennett
Aston Business School
This research is supported by the EC Alβan Programme.

This form is based on an example of a Volunteer Consent Form provided by Aston Business School Ethics Committee.

<u>VOLUNTEER CONSENT FORM</u>

Title of Project: Green Operations and Their Impact on the Automotive Industry

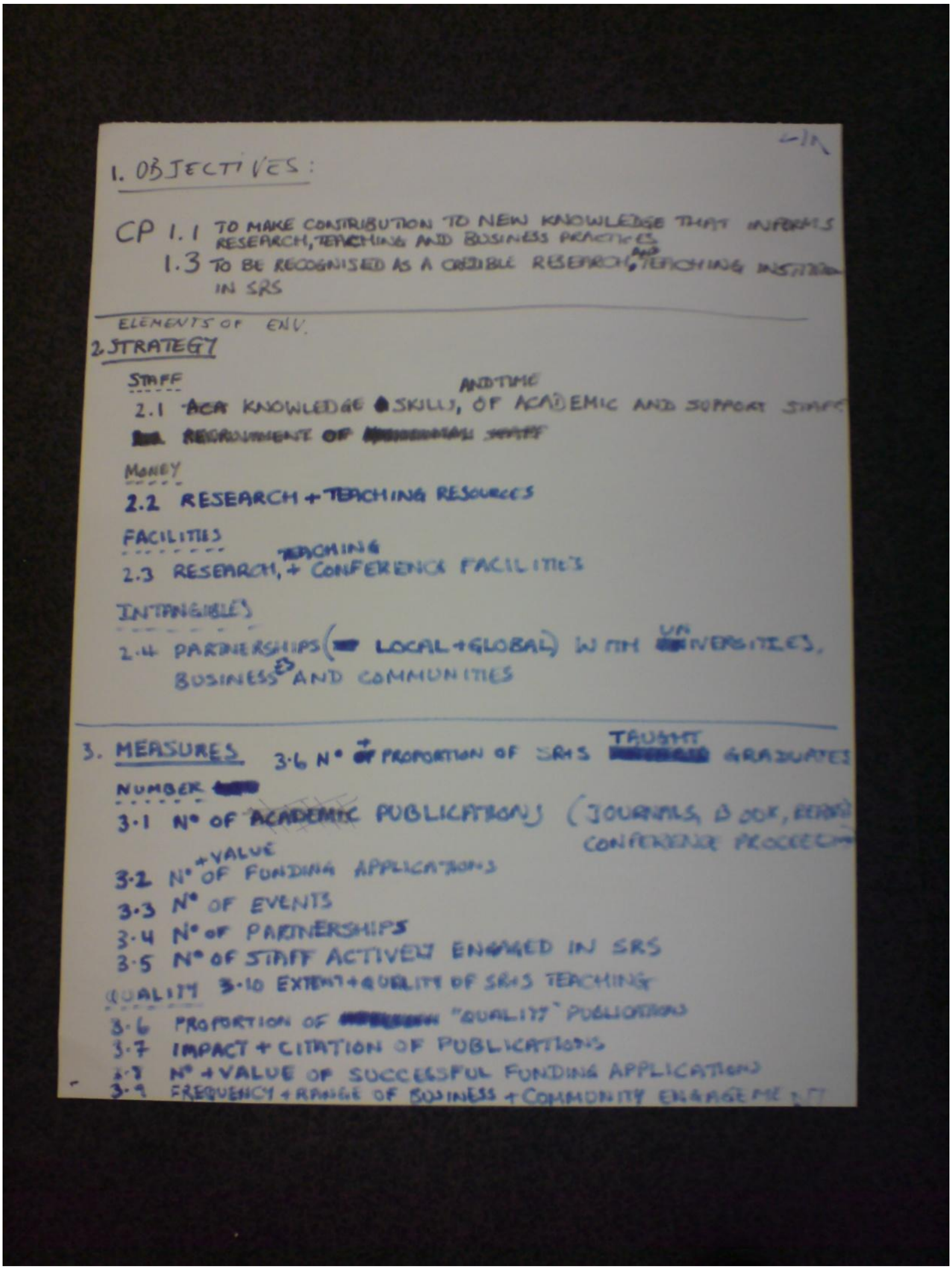
Name of Chief Researcher:

		Tick Box
1	I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.	
3	I agree to take part in the above study.	
4	I am aware that confidentiality will be respected. The material (research findings) will only be published and information about myself and my company will only be released with my previous approval.	
5	I allow the use of the real name of the company in the publications	

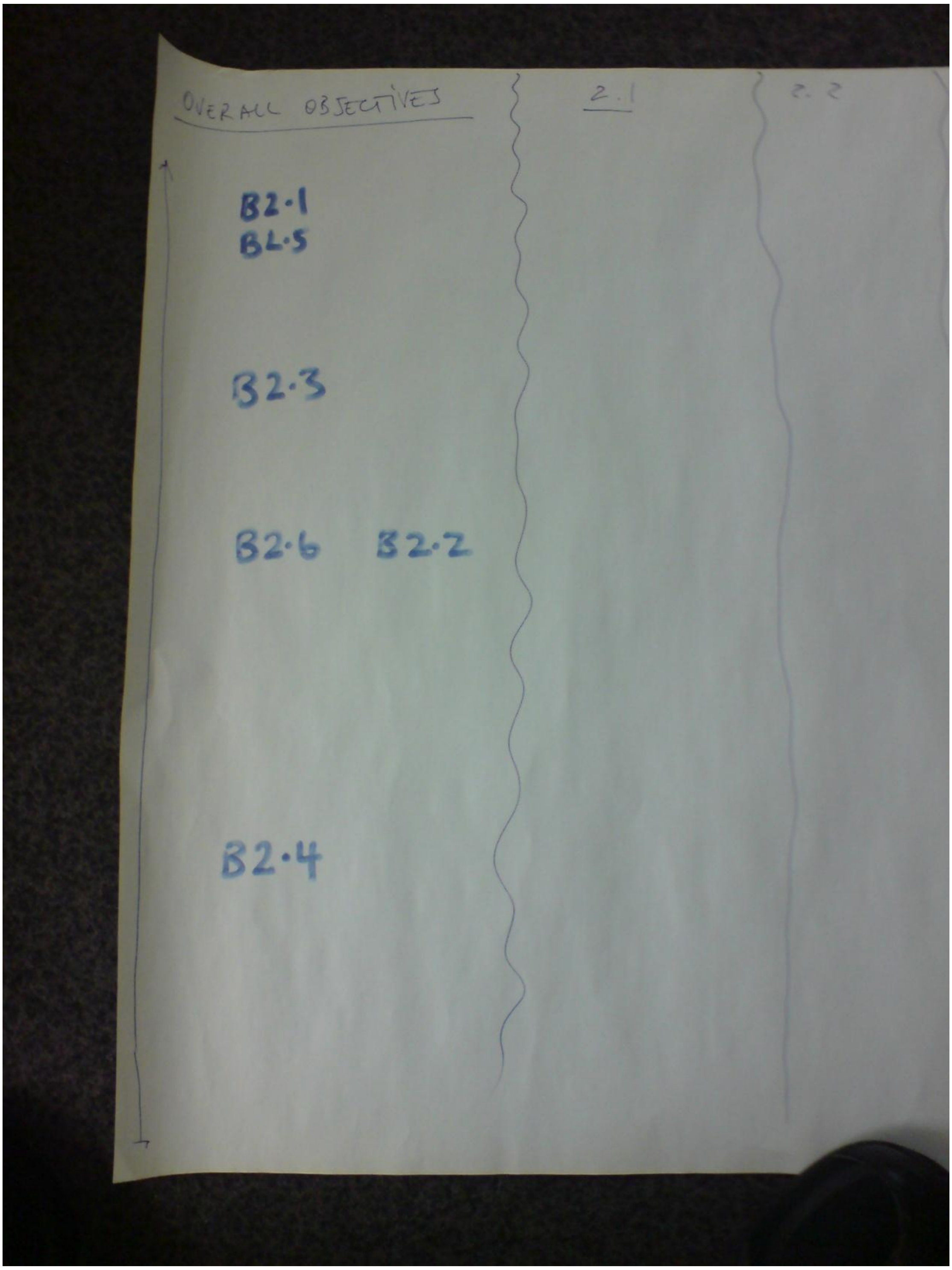
Name of volunteer	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

JGW/RPS 16.5.06

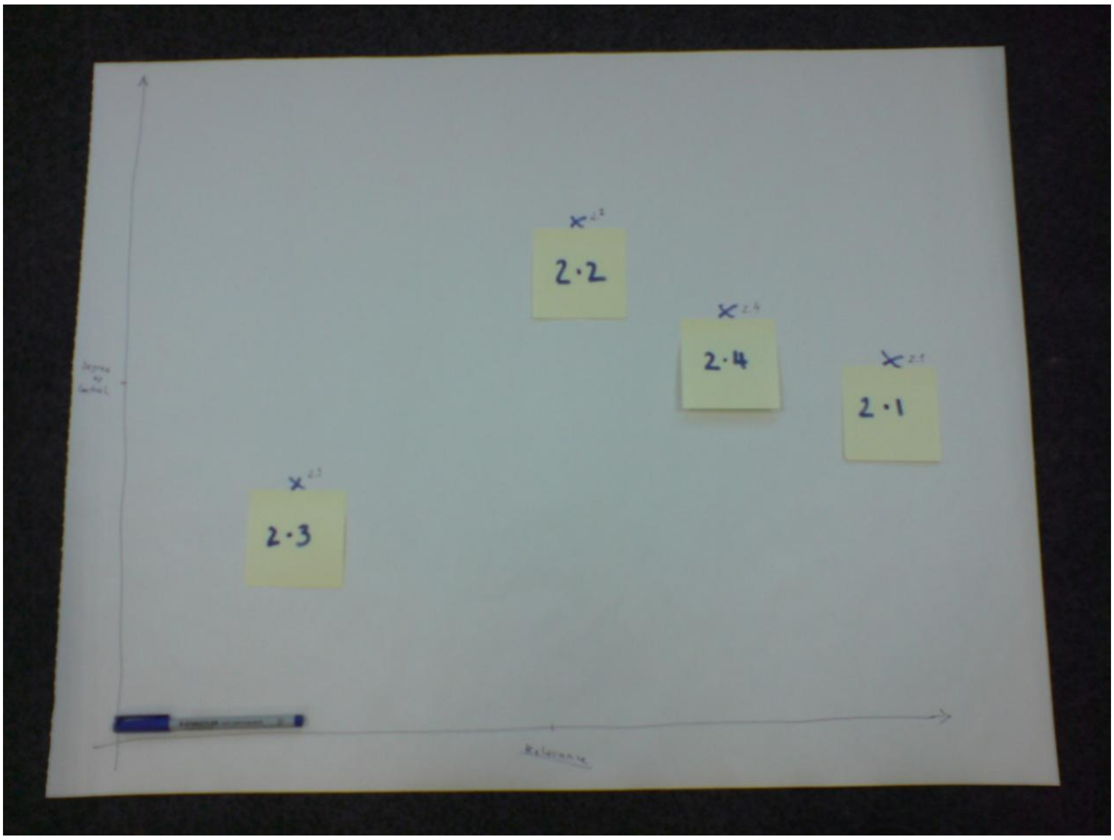
Appendix 7 – Focus group: Objectives of environmental strategy, Elements of environmental strategy, and performance measures



Appendix 8 – Ranking of the importance of environmental elements against overall objectives



Appendix 9 – Classification of the elements of environmental strategy according to their importance for environmental strategy and to decision makers' control (matrix degree of control versus relevance for environmental strategy)



Appendix 10 – The interaction between the elements of the environmental strategy

	Staff	Money	Research and Teaching (includes Facilities)	Intangibles
Staff		Salaries and on costs(N) Research Grants (P) New MSc (P) Events (N/P)	Need of space / accommodation offices (N) Teaching – better utilisation (P)	Partnerships (P)
Money	SR&S related Teaching / Research resources (P) Staff – recruit, retain, develop (P)		Technology (P) Teaching Resources (P) Library Resources (P) Research Assistants (P) Bursaries (P)	Visits (P) Conferences (P) Events (P)
Research and Teaching (includes Facilities)	Staff – recruit, retain, develop (P) Quality of teaching and research (P)	Capital + revenue costs (N) Research Grants (P) Student number (P) Events (P)		Partnering (P) Relationship / Politics (P/N) Working group (P) Conflict over facilities (N)
Intangibles	Staff – recruit, retain, develop (P) Time (N) Skills (P) Buy in / commitment (N)	Sponsorship (P) Research Grants (p) Events – if subsidised (N)	Teaching – external inputs (P) Access for research (P) Attendance response – other universities (P)	

Legend: (P) for Positive relationships and (N) for Negative relationships

Appendix 11 –The contribution of improvement actions for each element of environmental strategy

	Staff	Money	Research and Teaching (includes Facilities)	Intangibles
Resources	100	70	100	100
Recruitment	60	40	80	50
Funding	40	60	70	50
Bursaries	10	50	50	30
Curriculum	80	100	100	70
Events	20	80	20	90

Appendix 12 –The implication of 'not' doing improvement actions

	What are the implications of NOT doing?
(RESOURCES)	We fail in delivering the SR&S Strategy – SR&S marginalised Cross-discipline working
(RECRUITMENT)	Not attract / retain people
FUNDING	REF implications Not attract funding
(BURSARIES)	Not attract PhD students REF implications
(CURRICULUM)	Loss of students income Equis / PRME (UN) / AACSB failure Loss of grants
(EVENTS)	Loss of partners Loss of Credibility in SR&S Lack Reputation / Visibility

Appendix 13 – Results from the focus group

<table>
<tr><td colspan="2">Date: 30 September 2008</td></tr>
<tr><th colspan="2">Phase (A) Problem Identification & Objective Definition</th></tr>
<tr><td colspan="2">1. SR&S Objectives:
1.1. To make contribution to new knowledge that informs research, teaching, and business practices
1.2. To be recognised as a credible institution in SRS</td></tr>
<tr><td colspan="2">2. Elements of SR&S strategy
2.1. Staff: Knowledge, skills and time of academic and support staff
2.2. Money: Research and teaching resources
2.3. Facilities: Research, teaching and conference facilities
2.4. Intangibles: partnerships (local + global) with universities, businesses and communities</td></tr>
<tr><td>3. SR&S Performance Measures (Number)

3.1. Number of publications (journals, books, reports, conference proceedings)
3.2. Number and value of funding applications
3.3. Number of events
3.4. Number of partnerships
3.5. Number of staff actively engaged in SRS
3.6. Number and proportion of SRS taught graduates</td><td>SR&S Performance Measures (Quality)

3.7. Proportion of “quality” publication
3.8. Impact and citation of publication
3.9. Number and value of successful funding applications
3.10. Frequency and range of business and community engagement
3.11. Extent and quality of SRS teaching</td></tr>
<tr><th colspan="2">Phase (B) Development of Solutions</th></tr>
<tr><td colspan="2">1. Relevant area for improvement:
1.1. All academic Groups
1.2. All areas related to SRS</td></tr>
<tr><td colspan="2">2. Improvement actions
2.1. Provide Resources and Time and development for current academic and support staff to engage with SRS
2.2. Recruit academic and support staff with particular interest in SRS
2.3. Increase SRS funding applications
2.4. Provide bursaries for PhD students in the area of SRS
2.5. Implementation of SRS curriculum report
2.6. Organise SRS Events</td></tr>
</table>