KTH Industrial Engineering
and Management

Innovation Management:
Technology Strategies
for Sustainable Vehicle Development

Hamid Jafari Khaledabadi

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Master's Thesis in Production Engineering and Management
School of Industrial Engineering and Management

Supervisor: Thomas Magnusson
Examiner: Cornel Mihai Nicolescu

Royal Institute of Technology (KTH)
School of Industrial Engineering and Management
Department of Production Engineering
S-100 44 Stockholm, Sweden

Abstract

Recently, environmental concerns, rapid increases of petrol prices and regulatory efforts to restrain the threat of a global climate change are initiating a new type of technology-based competition within the automotive industry. Thus, new trajectories are appearing, and a severe competition is emerging regarding technological innovations in the very core of the product, the automotive power-train. This competition comes in addition to the existing process-based competition, which has been in focus for the industry for several decades. Thus, the automotive industry seems to be entering a period of extreme variation and experimentation marked by significant uncertainty. Hence, strategic decisions will have strong implications for the future of the industry. Critical decisions, on component as well as on system level, involve which technologies to invest in and which to stop developing, which alliances to form, which standards to commit to, etc.

This thesis studies the main drivers of sustainable vehicle development. Hence, based on a comprehensive theoretical framework on the concepts of sustainability and Corporate Social Responsibility, Innovation and Knowledge Management, the thesis aims at adding to the knowledge of industrial competition and technological innovation. Moreover, as most analyses of industrial evolution have primarily relied on retrospective studies, by adopting a real-time research approach, the thesis adds to this literature. The advantage of such an approach is that it provides an opportunity to learn from an ongoing and highly uncertain process. The thesis is focused on patent analysis and empirically, builds upon studies of European patent data on the main alternative fuel vehicle technologies – hybrid electric, battery electric, and fuel-cell – and on manufacturers' data on product releases.

Keywords: Innovation Management, Product Development, Automotive Industry, Sustainable Vehicles, Corporate Social Responsibility, Knowledge Management, Patent Analysis.

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Stockholm, May 2008

Hamid JAFARI

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Section I

THEORETICAL FRAMEWORK

1. Introduction

In the introductory chapter a background regarding the concept of innovation management in the automotive industry will be provided where the technology advancements and challenges in sustainable vehicle power-train and the reasons why these concepts are spotlighted today are presented. Thus, in this chapter, the research purpose will be stated.

1.1 Background

Environmental changes, long-term increases of petrol prices and regulatory efforts to curb the threat of a global climate change are initiating a new kind of technology-based competition within the automotive industry.

Road transport is the second-largest sector of energy consumption, right after energy needed for HVAC (heating, ventilation, air conditioning), where according to International Energy Agency (IEA, 2002, p.17), over the next 20 years, the energy demand growth in transport will be greater than in all other end-use sectors. In the European Union (EU) alone, emissions of greenhouse gases (GHG's) from transport (excluding international aviation and maritime shipping) increased by 19% between 1990 and 2000, contributing a fifth of total GHG emissions in 2000 (De Haan *et al.*, 2006).

Moreover, according to Van Mierlo *et al.* (2006), a report by the European Commission shows that between 1998 and 2010, the European transport will face a growth of passenger kilometers of 24% and good transport (ton.km) of 38%. Since the late 1960s the automotive industry has faced strict regulations, most remarkably related to local emissions, NO_X, CO, Volatile Organic Compounds (VOC's), fossil fuel use, and in more recently, GHG's, in particular, CO_2. According to De Haan *et al.* (2006), CO_2 is the main contributor to transport greenhouse emissions (97%) and road transport is in turn the largest contributor to these CO_2 emissions (92% in 2000).

Therefore, as Romm (2006) highlights, any energy and environmental policy effort must come to grips with transportation, since, roughly, 97% of all energy consumed by cars, sport-utility vehicles, vans, trucks, and airplanes is still petroleum-based. According to Van Mierlo and Maggetto (2007), revising their oil reserves, oil companies have recently forecasted a dramatic increase of oil prices towards 2040. This is providing that the maximum oil production could be reached within 10 to 15 year and naturally followed by a production decrease and demand exceeding the available supply.

Acording to Dincer (2006), environmental concerns are significantly linked to sustainable development. Woodcock *et al.* (2007) define *sustainability* as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. In a broader range, Corporate Social Responsibility (CSR) has received an unrivalled level of attention in the literature (e.g., Bowen, 1953; Carrol, 1999; Lantos, 2001; Dahlsrud; 2008), which according to Moon (2007), offers some potential contribution to sustainable development since it brings incentives for corporations to act socially responsibly. According to Schouten (2007), CSR deals with capturing the whole set of values, issues and processes that companies must address in order to minimize any harm resulting from their activities and to create economic (profit), social (people), and most importantly, environmental (planet) value. This involves being clear about the company's purpose and taking into account the needs of all the stakeholders; namely, shareholders, customers, employees, business partners, governments, local communities, and the public. Moreover, CSR benefits manifest an enduring competitive advantage (Smith, 2007)

In this regard, in the automotive sector – a once mature industry – new trajectories are emerging, and a dramatic competition is unfolding. This competition, which is based on technological innovation in the very core of the product – the automotive power train – comes in addition to the existing process-based competition, which has been in focus for the industry for several decades (Magnusson and Berggren, 2007). Thus, the automotive industry, which has been dependant on internal combustion engines (ICE's) for more than a century, seems to be entering an "era of ferment" (Anderson & Tushman, 1990) characterized by increased variation and experimentation. This period is marked by significant uncertainty, and strategic decisions will have strong implications for the future of the industry. In this regard, Critical decisions, on component as well as on system level, involve which engine technologies to invest in and which to stop developing, which alliances to form, which standards to commit to, etc.

Studies have shown that hybrid electric technology (HET), fuel-cell technology (FCT), and battery electric technology (BET) have been the most attractive technologies in alternative fuel vehicle (AFV) development (e.g., Magnusson and Berggren, 2007; Van den Hoed, 2007). Therefore, the main focus of this thesis would be on studying how the automotive industry is performing in developing and applying these technologies.

1.2 Research Purpose

The purpose of the thesis is to compare technology and product strategies of automotive manufacturers in response to the sharply raised demands on fuel efficiency and reduced CO_2-emissions.

By studying *technological discontinuities* in a well-established industry, the thesis will add to the knowledge of industry lifecycles and technological competition. Moreover, as most analyses of industrial evolution have primarily relied on retrospective studies (e.g., Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Tushman and Rosenkopf, 1992; Klepper and Simons, 2000), by adopting a real-time research approach, the thesis adds to this literature. This thesis a patent study is carried out. The advantage of such an approach is that it provides an opportunity to learn from an ongoing and highly uncertain process.

1.3 Problem Statement

The thesis is focused on automotive manufacturers active in the European market and, empirically, builds upon studies of European patent data and on manufacturers' data on product releases. The study aims at answering the following main questions:

- What are the main challenges and drivers of the automotive industry in sustainable vehicle development?
- How does technological knowledge (specifically patent) analysis contribute to innovation management?
- Which automotive companies are pioneers in sustainable vehicles and have been more active in patent registration in Europe?

1.4 Demarcations of the Thesis

As far as this thesis deals with innovation management in the automotive industry as a specific case, a major delimitation could be that the finding might not be generalizable to other industry sectors. Moreover, the main focus of the study is on power-train-related technologies and does not cover other automotive sections. Also, the patent analysis is carried out in the European Patent Office database. Obviously, the results could be different from that of the US Patent and Trademark Office (USPDO) or its Japanese counterpart (Japan Patent Office). Also, despite the fact that a rather wide time span was chosen for the patent study – from 1990 to 2007 – the patent database for the year 2007 might not be complete since some issued patents were pending for publication at the time of the study. Moreover, the automotive industry involves a broad range of alliances and partnership which makes the classification task in the patent and sales study rather difficult.

1.5 Disposition of the Thesis

The first section of the thesis is dedicated to the theoretical framework and literature study where the issues of Sustainability, Innovation Management, and Knowledge Management are discussed in Chapters 2 to 4.

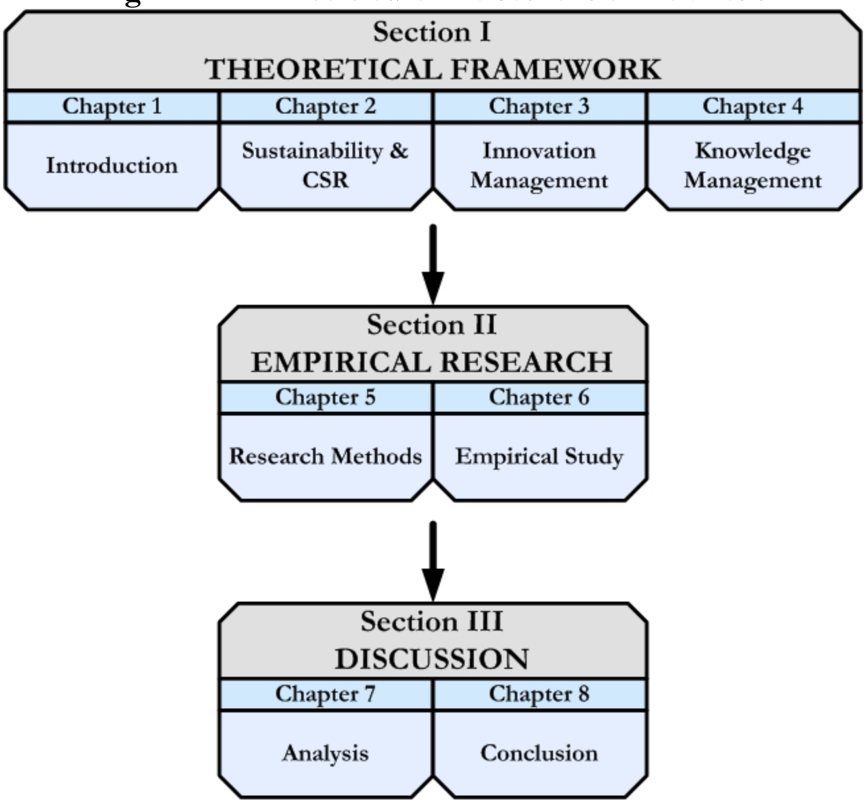
It is to be noted that the theoretical framework of the thesis has a marketing track; wherein, the marketing reflections are provided in several parts in each chapter (e.g., 2.1.3 on Going "Green"; 2.2.4 on Corporate Social Responsibility and Marketing Management; 3.3.3 on Market Innovation; 3.6

on Innovation Adoption: The Technology Acceptance Model; and 4.7 on Knowledge Management and Marketing). Moreover, in the empirical study, the sales data are provided for some automotive companies.

The second section deals with the empirical study of the thesis. In this section, first the research method being applied in the study is discussed in Chapter 5, and thereafter, the main engine technologies are presented in Chapter 6. Moreover, a comprehensive patent study of the main engine technologies – hybrid-electric, fuel-cell, and battery-electric – is carried out, and the respective product sales data of the leading companies is provided.

The third section entails the analysis of the patent and sales data in the framework of Sustainability, Innovation, and Knowledge Management discussed earlier in the first section, where some managerial implications are provided in Chapter 7. Finally, a brief conclusion of the thesis is provided in Chapter 8. An illustration of how different sections are organized is depicted in Figure 1-1.

Figure 1-1 An Overview of the Sections of the Thesis



2. Sustainability and Corporate Social Responsibility

In this chapter, the two mainstay concepts of Sustainable Management and Corporate Social Responsibility will be overviewed where their effect on Innovation Management will be highlighted. Furthermore, some Strategic and Marketing Management perspectives will be covered.

2.1 Sustainable Management

In today's technological innovation policies, there has been a great concern about the environmental issues. In this regard, sustainable management has gained prominent importance. This has prompted researchers to call for a re-conceptualization of a firm's environment and a reframing of the role of the environment in strategic decision-making (McLarney, 2003). A wide area of research has been devoted to this issue.

2.1.1 Background

Recently, there has been an ever-increasing interest regarding the environmental impacts of technologies; including, acid rain, stratospheric ozone depletion and global climate change. In this regard, a variety of potential solutions to the current environmental problems associated with the harmful pollutant emissions have evolved. The current atmospheric concentration of greenhouse gases (GHG), 430 ppm CO_2-equivalents (CO_2-e), is already 50% higher than the pre-industrial level and annual emissions are rising fast. Even if annual emissions remain at the current level they will take GHG concentrations above 650 ppm CO_2-e by the end of the century, enough to result in a global mean temperature rise of 3^{oC}. Such a rise will mean regular and serious droughts and floods, and coastal flooding, water shortages for billions of people, massive extinction of species, and rising risks of abrupt changes in regional climate systems (Stern, 2007).

The Kyoto Protocol introduced in 1997 was the first step towards a world-wide agreement to reduce greenhouse gas (GHG) emissions, and in 2005 implementation of the agreement was initiated. In order to accomplish the goal of the protocol, a portfolio of governmental policies must be implemented to change the behaviors of consumers as well as producers (Olsson *et al.*, 2006).

All organizations have some impact on the natural environment, particularly through the resources they use, the processes and activities they undertake, and the waste they create. However, many organizations do not actively seek ways of reducing these impacts.

Environmental management is defined by Whitelaw (1997) as "the process whereby organizations assess, in a methodical way, the impacts of their activities on the natural environment, and take action to minimize these impacts". An Environmental Management System is a management system that allows an organization to control its environmental impacts and reduce such impacts continuously. As Dincer (2006) highlights, environmental concerns are significantly linked to sustainable development. Activities which continually degrade the environment are not sustainable. Woodcock *et al.* (2007) define *sustainability* as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

2.1.2 Transportation Concerns

Transport-related carbon emissions are rising and there is an increasing consensus that the growth in motorized land vehicles and aviation is incompatible with averting serious climate change (Woodcock *et al.*, 2007). In other words, the transport sector is one of the most significant contributors to "environmental unsustainability" (Olsson *et al.*, 2006). In the mid 1960s, three pollutants from automobile exhaust were identified for control; namely, hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_X). Other tail-pipe pollutant emissions include CO_2, ozone, benzene, lead, and particulate matter.

According to a report by the International Energy Agency (IEA, 2002, p.17), over the next 20 years, the energy demand growth in transport will be greater than in all other end-use sectors. Transport's share of total energy use will increase from 28% in 1997 to 31% in 2020. Furthermore, as Woodcock *et al.* (2007) highlight, motorized transport is over 95% dependent on oil and accounts for almost half of world use of oil.

GHG emissions from transport are projected to continue to rise rapidly. Therefore, sustainable transport has become a key global transport objective. In Western Europe, freight transport has more than doubled since 1970, with road and short sea-shipping taking the largest shares (44% and 41%, respectively). In Eastern Europe, the 1990s witnessed a major decline in rail transport and a concurrent increase in car and truck use (Woodcock *et al.*, 2007). Figure 2-1 depicts the projected growth in transport emissions of carbon dioxide to 2030[1]. It shows that by the next 30 years, the CO_2 ascribed to transport will be almost doubled.

[1] OECD stands for the Organization for Economic Co-operation and Development

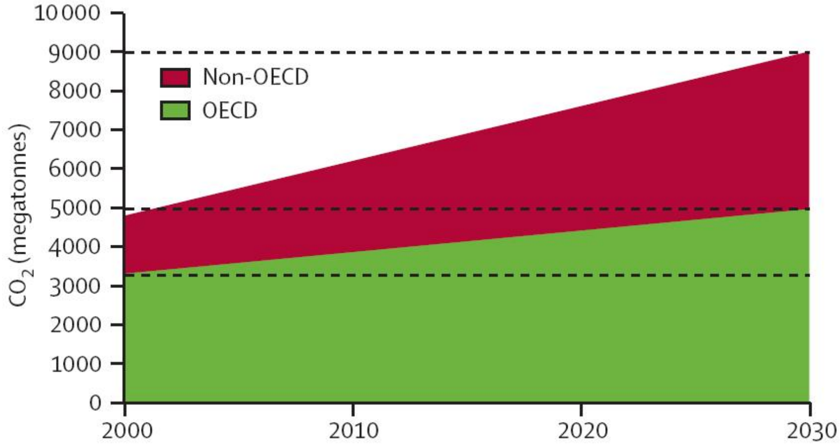


Figure 2-1 Projected growth in transport emissions of CO_2
Source: Woodcock et al. (2007)

2.1.3 Going "Green"

Greening of industry is a broad research field with global and general strategic views, and debates on how to reach them. Moving inside the firm, more detailed research issues arise such as ethical aspects, organizational culture, company insurance issues, management compensation schemes, corporate non-monetary measures, production oriented aspects, product oriented aspects, and in more general economic terms for the firm, whether it pays to be green or not (Williander, 2006). According to Ottman (1998), consumers will pay up to a 10% premium for a product that is more environmentally-friendly than current goods.

Since the mid 1960s, the automotive industry has done a remarkable job of engineering systems to control emissions from automobiles. Greening such an industry is not a matter of providing more eco-benign products to the consumer, but of achieving a regime shift affecting multiple businesses and networks, and to change an integrated system of technologies and social practices (Kemp *et al.*, 1998). Improved engine design and changes in fuel source are important for reducing emissions. As alternative fuels in the long run will be improved, a positive "spill-over effect" might be that motor vehicles running on fuels with less CO_2 emission will become a more appealing product for both car manufacturers and consumers (Olsson *et al.*, 2006). A measure of the industry's success is the fact that, by the 21st century, tailpipe emissions of HC, CO, and NO_X have been reduced by 99%, 96%, and 95% respectively to 1965 levels (Mondt, 2000, p. 213). However, despite efforts to use alternative fuels, oil will continue to dominate the sector. Besides the energy security and sustainability implications of this dependence on oil, transport will also generate roughly one-fourth of the world’s energy-related CO_2 emissions.

2.1.4 Sustainability and Strategic Management

At the organizational level, many studies have addressed environmental issues in relation to the strategic management and capabilities of firms. In this regard, according to Berchicci and Bodewes (2005), three main views have been adopted by researchers namely; 1) the resource-based view (RBV) since it defines competitive advantage as the outcome of organizational capabilities that result from a proactive environmental strategy, 2) in-depth investigations as to why firms respond to environmental issues, adopting institutional theories to explain how organizations become more aligned with the institutional environment with its environmental regulations, mimicry and normative pressure, and 3) investigating the individual and contextual factors that influence the decision on whether or not to embrace environmental issues, adopting theories of planned behavior. According to Treibswetter and Wackerbauer (2008), studies of environmental innovation over the last ten years have found that regulation is the most important stimulus for innovation.

In a model proposed by McLarney (2003), the connection between environmental turbulence, strategic planning processes, and effectiveness is studied. The model is depicted in Figure 2-2. From the model one can observe that the level of environmental turbulence is linked to the components and contextual elements of strategic planning processes. Moreover, a number of linkages exist between the constructs. First, the model suggests that as the level of environmental turbulence increases, the components and contextual elements of an organization's strategic planning process will change. Therefore, organizations operating in highly turbulent environments will stress different components and contextual elements in their strategic planning process than organizations in relatively lower turbulence environments.

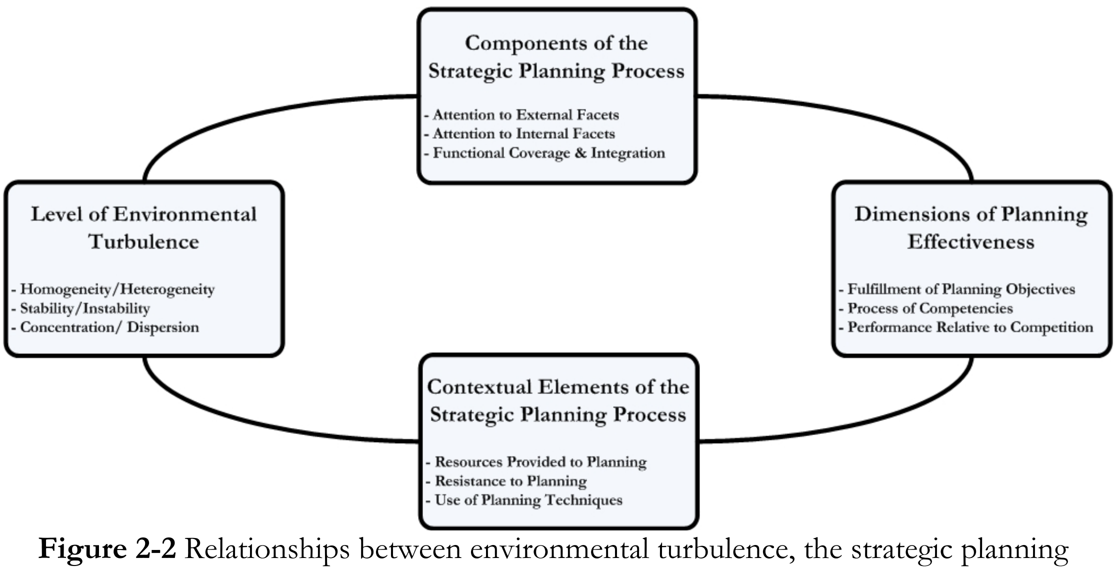


Figure 2-2 Relationships between environmental turbulence, the strategic planning system process and effectiveness

Source: McLarney (2003)

As identified in the model, these components and contextual elements vary from attention to external and internal facets to resources and techniques used in the planning process. Second, the model suggests that as organizations stress certain components and contextual elements of their strategic planning process these planning processes will be relatively more effective compared to similar organizations. Finally, as these organizations put more emphasis on particular process components and contextual elements, they will evaluate the effectiveness of that process differently (McLarney, 2003).

According to Steger (1993), with regards to environmental strategies and market opportunities, companies could be categorized to:

1. Indifferent (with few environmental risks and few market opportunities);
2. Defensive (with major environmental risks and few market opportunities);
3. Offensive (with few environmental risks and major market opportunities), and
4. Innovative (with major environmental risks and major market opportunities).

Roome (1994) establishes a link between the level of ambition in the area of the environment and the associated organizational changes. At the same time, he makes a distinction between first-, second- and third-order changes. A first-order change adds new techniques and technologies but leaves the structure and values within the company unchanged. A second-order change consists of the gradual modification of existing organizational structures, systems, objectives and values within the company. Such a change process may be accompanied by, for instance, training of personnel at all levels (Cramer, 1998). A third-order change is aimed at achieving excellence in the area of the environment.

In this regard, strategic niche management has arisen as an efficient policy approach to promote innovation. It is a concept aiming at the substantially more complex shift of technological regimes that requires change not only in consumer preferences, and potentially in price structure, but in supporting infrastructures and potentially also in regulation (Kemp *et al.*, 1998). The strategic niche management approach proposes a multi-stakeholder conscious management of a niche in which an alternative to a dominant technology is given a chance to grow in strength and demonstrate viability from various aspects before being further disseminated into society. The approach emphasizes the need for co-evolution and mutual adaptation between the alternative technology and the system in which it is produced and used. This mutual adaptation is not likely to take place under conditions of tough competition from already established and socially embedded technological regimes, but requires a niche in which it can be tested, modified and grow in strength, while simultaneously being promoted to become an alternative for broader consumer groups to consider. The required co-evolution and mutual adaptation between the alternative technology and its environment is proposed to take place through an articulation and learning process that stimulates organizational change, building of constituency and creation of social desirability (Williander, 2006). Typically, market penetration starts with a small segment (Gärling and Thøgersen, 2001).

2.2 Corporate Social Responsibility

Corporate Social Responsibility has gained prominent attention recently as a critical factor affecting success and image of businesses.

2.2.1 Background

Corporate Social Responsibility (CSR) and ethics are two of the key challenges faced by management in recent years which have proven to provide companies with sustainable competitive advantage. According to Robin and Reidenbach (1987), CSR is related to the social contract between business and society in which it operates, while business ethics requires organizations to behave in accordance with carefully thought-out rules or moral philosophy. Socially responsible behavior may be ethically neutral or even ethically unsound while actions dictated by moral philosophy may be socially unacceptable (Fan, 2005). As Carrol (1999) maintains, CSR has developed as a concept from basic philanthropy by business leaders to a facet of modern business and management itself.

According to Moon (2007), CSR offers some potential contribution to sustainable development since it brings incentives for corporations to act socially responsibly. He further contends that CSR and sustainable development are often accused of being contradictions in terms. This is due to the fact that one assumption holds that corporations are incapable of social responsibility and the other being that sustainability of the planet and its resources and integrity is incompatible with economic (and, in cases, social) development. Also, both terms are often used vaguely and even interchangeably.

From the 1950s onward, business scholars have provided various definitions of CSR and of related notions such as corporate citizenship, corporate social responsiveness, sustainable development, corporate ethical behavior, or corporate social performance (e.g., Bowen, 1953; Robin and Reidenbach, 1987; Lantos, 2001; Papasolomou-Doukakis *et al.*, 2005; Wan-Jan, 2006). In a comprehensive review of CSR definitions, Dahlsrud (2008) highlights five main dimension; namely, environmental, social, economic, stakeholder, and voluntariness. In this study, the definition provided by World Business Council for Sustainable Development (2000) seems to be among the most inclusive definitions; where CSR is defined as "the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as the local community and society at large". According to Moon (2007), CSR is a form of self-regulation to contribute to social (including environmental) welfare.

In Europe, the concept of CSR is the subject of many boardroom discussions, and in the USA the Dow Jones publishes a CSR index on the premise that many investors believe firms who practice social responsibility provide better long term financial returns. The intent of CSR is to add value to society, to leave the world in a better position for the next generation by building environmental and social responsibilities into the traditional economic equation. Proponents of CSR claim that this approach will restore public trust and respectability in the corporation, while the opponents state that the concepts of CSR only reflect appropriate standards of corporate governance and there is no need for CSR as a separate movement (Weymes, 2004).

2.2.2 CSR from a Strategic Management Perspective

CSR has been associated with different underlying strategic purposes such as legitimacy, responsibility for externality, and competitive advantage (Moon, 2007). Enderle (2004) suggests that firms have three responsibilities to society: economic, social, and environmental. Lantos (2001) maintains that in relation to social responsibilities, corporations should fulfill the following responsibilities:

- ethical CSR (including economic, legal and ethical as one group),
- altruistic CSR (philanthropic, going beyond ethical, regardless of whether or not this will benefit the business itself), and
- strategic CSR (fulfilling those philanthropic responsibilities which will benefit the firm through positive publicity and goodwill).

With a similar perspective, Galbreath (2005) suggest that from a strategic perspective, businesses have four CSR strategic options to consider: first, the shareholder strategy; second, the altruistic strategy; third, the reciprocal strategy; and fourth, the citizenship strategy.

2.2.3 CSR and Competitive Advantage

One reason why social responsibility provides a sustainable competitive advantage is that it requires a culture that can successfully execute a combination of activities (Smith. 2007). According to Zadek (2006), the potential of competitiveness is grounded in several tiers or ways in which competition between nations and communities takes place:

- Direct, specific business benefits,
- Corporate responsibility clusters,
- Innovation and flexibility (Zadek, 2006).

Responsible competitiveness can arise through the impact of corporate responsibility on business innovation and flexibility. This can take two forms. The micro-level argument is essentially a sub-set of the broader "business case" view of corporate responsibility. Rather than viewing business benefits in static terms, such as reputational and brand gains, or even recruitment and motivational benefits, the innovation argument suggests that corporate responsibility enables businesses to become better, for example, at developing new products, processes and distribution channels. The macro-institutional innovation effects are potentially, however, the most important for responsible competitiveness. At its heart is the argument that suggests credible, responsible business practices:

- Strengthen the legitimacy of the business community
- Enhance trust between it and other key institutional players, such as labor organizations and public bodies
- Reduce labor-related conflicts and burdensome statutory regulations
- Increase the flexibility of business to respond to changing market circumstances.

Historically, a concentration on improved operational effectiveness and overcapacity created a temporary economic advantage accompanied by increased profit and firm value. Such an advantage is short-lived; investors may be satisfied, but competing companies will eventually mimic technological and material improvements (Smith, 2007). This short-lived economic advantage is in direct contrast to CSR, which produces a sustainable competitive advantage attributable to positive organizational reputation. The socially perceived image of the company depends upon the marketing of strategies like the four Es; namely, make it easy for the consumer to be green, empower the consumers with solutions, enlist the support of the customer, and establish credibility with all publics and help to avoid a backlash (Pearce and Robinson, 2005).

According to Faulkner *et al.*, (2005), the environmental management literature routinely argues the negative short-termist case, that it is possible for industries and organizations to advance their business interests while lessening their adverse environmental impacts; the so-called "Porter hypothesis". It also presents a number of cases which support the more positive long-term proactive stance by highlighting "economic opportunities" offered by the environment. These include environmentally motivated production improvement programs, market development approaches, like those associated with green marketing, the sale or reuse of waste by-products through concepts such as eco-industrial development.

2.2.4 CSR and Marketing Management

A number of market drivers have been emerged that contribute to the growth of CSR; namely, consumers, employees, investors, business suppliers, and customers (Moon, 2007). Marketing stakeholders can be viewed as both internal and external; where internal stakeholders include functional departments, employees, and interested internal parties. External stakeholders include competitors, advertising agencies, and regulators (Miller and Lewis, 1991). Another view of stakeholders characterizes them as primary or secondary. Primary stakeholders are those whose continued participation is absolutely necessary for business survival; they consist of employees, customers, investors, suppliers, and shareholders that provide necessary infrastructure. Secondary stakeholders are not usually engaged in transactions with the focal organization and are not essential for its survival; they include the media, trade associations, non-governmental organizations, along with other interest groups. Different pressures and priorities exist from primary and secondary stakeholders (Waddock *et al.*, 2007).

CSR can be seen as one element in a larger branding strategy. According to Michael (2003), by engaging in CSR programs, marketing and auditing them, CSR can attract demand from market segments particularly interested in social issues. Corporate identity and reputation, both important to marketing, are created by business actions and communications with stakeholders (Christen and Askegaard, 2001; Dowling, 2001; Maignan *et al.*, 2005). Firms advertise their affection to public claims to enhance their corporate image. Advertisement of the adoption of CSR provides a sustainable advantage amongst competitors through improved appearance which is intangible and difficult to duplicate. Competitors seeking to match the CSR competency of a firm will find themselves slow to capture the consumer loyalty or governmental trust. The organizational impacts of a positive public image compound; not only can the firm expect increased sales and revenue, but also greater employee satisfaction, the attraction of new investors, and tax exemptions (Smith, 2007).

Table 2-1 Main Stakeholders Issues in Marketing and CSR

Stakeholder Group	Issues in Marketing and CSR
Employees	Compensation and benefits
	Training and development
	Employee diversity
	Occupational health and safety
	Communications with management
Customers	Product safety and quality
	Management of customer complaints
	Services to disabled customers
Investors	Transparency of shareholder communications
	Shareholder rights
Suppliers	Encouraging suppliers in developing countries
	Encouraging minority suppliers
Community	Public health and safety protection
	Conservation of energy and materials
	Donations and support of local organizations
Environmental Groups	Minimizing the use of energy
	Minimizing emissions and waste
	Minimizing the adverse environmental impacts of products/services

Source: Maignan et al. (2005)

In this regard, cause-related marketing (CRM) or so-called third wave branding is a new concept in marketing. The idea behind CRM is that aligning companies with causes that consumers feel strongly about, will create social capital and there will be a strong association between consumers and companies (Dowling, 2001).

According to Maignan *et al.* (2005), the level of social responsibility of an organization can be assessed by scrutinizing its impacts on the issues of concern to all defined stakeholders. Table 2-1 provides examples of common stakeholder issues that impact marketers and may need to be considered in CSR decision-making.

Clear organizational values and norms are also needed to select among conflicting stakeholder demands. A given organization could indeed be faced with equally powerful stakeholders whose views of CSR imply differentiated business practices. For example, while customers may demand environmentally friendly products, shareholders may question green invest-

Table 2-2 Market dynamics of responsibility

Scenario	Description	Outcome
First mover advantage	Where businesses can gain a distinct advantage by being the first to introduce a particular responsible business practice, e.g. Toyota Prius	Competitors seek to erode the leader's advantage increasing the likelihood that the practice mainstreams into the market
Lone mover	Where one business finds itself under intense public pressure, which does not spill over onto its competitors. Examples include Nike in its handling of labour standards in global supply chains, and BP and Shell in the cases of human rights	Unless the costs of lone moves are negligible or the company has other market advantages, such as a premium brand, the development is likely to be competed out of the market or remain in a small niche
First mover disadvantage	Where no company can make a viable business case for investing in the changes needed to achieve better social and environmental outcomes since the costs and benefits do not add up at an individual company level	The changes generally do not happen if the market players are left to operate as individual competitors

Source: Zadek (2006)

ments because of their high costs and uncertain returns. Accordingly, organizational values and norms are especially useful to guide CSR practices when they specify the nature of either relevant stakeholder communities or important stakeholder issues (Maignan *et al.*, 2005).

According to Moon (2007), there are clear niche markets of consumers who are prepared to pay more for goods and services that they consider socially responsible (e.g., cosmetics free from animal testing; organic foods; ethically sourced coffee and chocolate).

The economics of responsibility are subject to underlying market dynamics (as shown in Table 2-2), like any other aspect of business performance. It is these dynamics that can amplify or undermine responsible behavior. Such dynamics do not merely involve businesses, but can and do engage non-market actors, civil society organizations and national and international public bodies. Indeed, it is collaboration between these diverse players that in practice has driven some of the most important instances of scaling up responsible business practices (Zadek, 2006).

Maignan *et al.* (2005) propose a systematic approach for implementing CSR. This methodology outlines the steps to be adopted to properly implement CSR from a marketing perspective. In particular, the methodology advanced is aimed at introducing a coherent CSR program where marketing decisions are driven by a fit with organizational values and norms. An overview of the proposed methodology is provided below:

STEP 1: Discovering organizational norms and values,
STEP 2: Identifying stakeholders,
STEP 3: Identifying stakeholder issues,
STEP 4: Assessing the meaning of CSR,
STEP 5: Auditing current practices,
STEP 6: Implementing CSR initiatives,
STEP 7: Promoting CSR, and
STEP 8: Gaining stakeholder feedback.

2.3 Summary

This chapter dealt with the concepts of Sustainability and CSR which have gained an unprecedented level of attention recently and have been recognized as main drivers of a vast domain of innovations. So, by highlighting the reasons of major innovations in automobile power-trains, this chapter, basically, serves as a foundation on which this thesis is built on. In the following chapters, the concepts of Innovation Management and Knowledge will be discussed comprehensively.

3. Innovation Management

In this chapter, the concept of Innovation Management will be discussed where its importance in gaining a sustainable competitiveness will be highlighted. Moreover, innovations in products, processes, and markets, and the literature on disruptive and incremental innovations will be overviewed. Finally, a brief look at innovation phases and performance measurement will be provided.

3.1 Background

In today's highly dynamic and competitive business environment, companies are exposed to severe challenges with meeting the ever-increasing market and customer needs and expectations, coping with sophisticated regulations and requirements, and facing technological obsolescence. In this regard, the concept of innovation is gaining prominent significance as a means of sustaining performance and growth.

Innovation has a connotation of "newness", "success", and "change" (Assink, 2006) and can be defined respectively as "the generation, development, and adaptation of an idea or behavior, new to the adopting organization" (Damanpour, 1996), "The first successful application of a product or process" (Cumming, 1998), and with regards to change: "innovation is conceived as a means of changing an organization, either as a response to changes in the external environment, or as a pre-emptive action to influence the environment" (Damanpour, 1996). In another view, Kumar *et al.* (2000), define innovation as something that is *invented* for the first time and is a commercial success. However, the concepts of innovation and invention have been widely distinguished in the literature (e.g., Trott, 2001; Tidd *et al.*, 2005).

3.2 Innovation Management: A Key to Competitiveness

Many authors (e.g., Tidd *et al.*, 2005) have regarded innovation as a key factor for a company to survive and grow on the long run.

Despite the successful implementation of innovations, only a few companies have come to understand what is necessary for successful innovation. Shepherd and Ahmed (2000) maintain that the ways in which companies meet these challenges depends largely on the nature of the business they are in, the dynamic forces of the market in which they operate, and the resources and skills that can be applied to ensure their business objectives are met.

According to Pratali (2003), managing innovation involves two simultaneous, interrelated fundamental objectives of competitiveness: improving product quality (a prerequisite to success), and improving the company's overall technological quality (a prerequisite to lasting success).

Innovation has been regarded as a dependable way to generate long-term stability, achieve shareholder returns, maximize employee satisfaction, and stay at the forefront of the industry through attaining a sustainable position (Davis and Moe, 1997; Cottam *et al.*, 2001).

3.3 Innovation Types

Johne (1999) distinguishes categorizes innovations into three types; namely,: product innovation, process innovation, and market innovation. In a relevant study, Johannessen *et al.*, (2001) distinguish six classes of innovation; namely, new products, new services, new methods of production, opening new markets, new sources of supply, and new ways of organizing. Product and process innovation are distinguished from market innovation. Edquist (1997) also classifies innovation by aggregation level. In a yet similar study, Assink (2006) classifies the object of innovation as things (i.e., products and services), or as changes in the way we create and deliver products and services (i.e., processes). Other objects of innovation are the organization, transactions, management style, and business model. These types of innovation relate mainly to process innovation.

Here, the former classes of innovation – product, process, and market – will be reviewed.

3.3.1 Product Innovation

Product innovation, according to Freeman (1982), is a process that includes the technical design, R&D, manufacturing, management, and commercial activities involved in the marketing of a new or improved product. It provides "the most obvious means" (Johne, 1999) for generating revenues.

Wheelwright and Clark (1992) relate the importance of product innovation to three major trends; namely, intense international competition, fragmented and demanding markets, and diverse and rapidly changing technologies.

According to Langley *et al.* (2005), as opposed to minor innovations that comprise small-scale alterations to existing products, major product innovations involve a completely new set of attributes, form a new product category, and induce behavioral changes on behalf of the users. Furthermore, the production and marketing of new product categories typically calls for new market actors, and thereby induces new patterns of interaction in the market. As Gee (1981) highlights, product innovation implies two major conditions: novelty and use.

In this realm, to meet the various challenges in new product development (NPD) and product innovation, organizations have considered the concept of fast product innovation, which according to Hardaker (1998), needs to be based on a close alignment between technology, products and markets, with a focus on achieving increased aggregate value. Moreover, in this regard, knowledge management and skills in the process of new product creation play key roles in earning competitive advantage (Teece *et al.*, 1997). This issue will be addressed later on in Chapter 4.

3.3.2 Process innovation

Although new products have been regarded as the "cutting edge" of innovation in the marketplace (Tidd *et al.*, 2005), innovations in processes have proven to have a significant strategic effect in competitiveness.

Process innovation embraces quality function deployment and business process reengineering (Cumming, 1998). According to Johne (1999), it provides the means for safeguarding and improving quality and for saving costs. He also maintains that process innovation is important in both the supply of the core product as well as in the support part of any offer.

3.3.3 Market Innovation

Although product and process innovation have proven to be a means of competitiveness (cf. Johne, 1999), it seems clear that innovative products do not assure success unless the importance of marketing is taken into consideration. According to Johne (1999) market innovation is concerned with improving the mix of target markets and how chosen markets are best served. Its purpose is to identify better (new) potential markets; and better (new) ways to serve target markets.

Tidd *et al.* (2005) highlight that before applying standard marketing techniques, firms must have a clear idea of the maturity of the technologies and markets. They further propose a two-by-two matrix model (depicted in Figure 3-1) by which they study the correlation of technology maturity and market maturity.

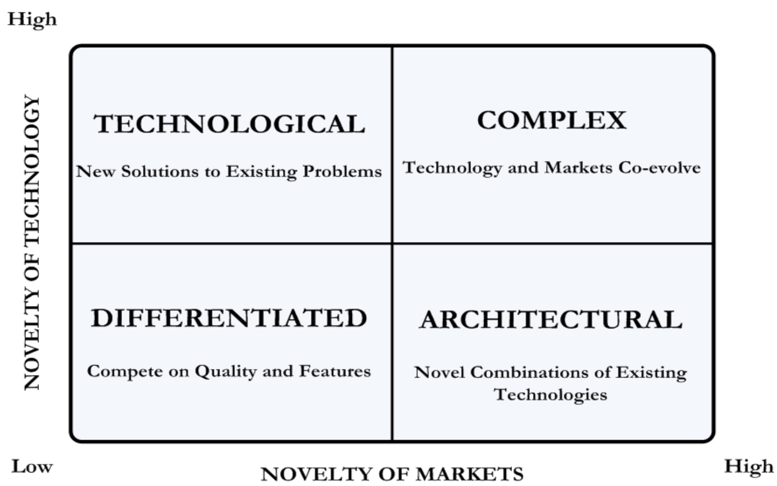


Figure 3-1 Technological and Market Maturity Correlation
Source: Tidd et al. (2005), p. 243

Following, a brief overview of the quadrants is provided:

- *Differentiated:* Both the technologies and markets are mature, and most innovations consist of the improved use of existing technologies to meet a known customer through packaging, pricing, and support.
- *Architectural:* Existing technologies are applied or combined to create novel products or services, or new applications; wherein, competition is based on serving specific market niches and on close relations with customers; and according to Henderson and Clark (1990), often can be accommodated within old frameworks.
- *Technological:* Novel technologies are developed which satisfy known customer needs. Here, innovation is basically driven by developers and competition is based in performance rather than price or quality.
- *Complex:* Both technologies and markets are novel, and co-evolve. Here, there is no clearly-defined use of a new technology; however, developers work with lead users to create new applications (Tidd *et al., 2005).*

In the case of complex products or services, according to Tidd *et al.* (2005), technology and markets co-evolve over time, since neither since they are poorly-defined or understood. They also contend that the buying process for such products is likely to be lengthy due to the difficulty of evaluating risk and subsequent implementation.

In this regard, the concept of market segmentation, which involves dividing a total potential market into smaller more manageable parts, is critically important if the aim is to develop the profitability of a business. Meanwhile, some authors argue that market research results frequently produce negative reactions to discontinuous products (discussed in 3.4.1) that later become profitable for the innovating company (e.g., Trott, 2001).

Moreover, in the realm of product development, Quality Function Deployment (QFD) has proven to be an effective methodology for translating customer needs and expectations into development requirements. The technique tries to capture opportunities for product improvement or differentiation through the collaboration of design and engineering, production, and marketing departments.

3.4 Incremental vs. Disruptive Innovations

Abetti (2000) contends that innovation may be highly radical, radical, intermediate, significant incremental, or minor incremental. Similarly, according to Assink (2006) innovation covers the continuum from incremental or sustainable innovation (remodeling functionality) to radical or disruptive innovation (breakthrough, paradigm shift). Thus, innovation can take place at an individual level (improvement), at functional level (process improvement or adaptation), at company level as an entire value chain (radical product and service innovation, new business models), and at industry level (technology breakthroughs) as systems of innovation.

3.4.1 Disruptive Innovations

Radical innovations, according to Sandberg and Hansén (2004), are innovations that involve significant new technologies, require considerable change in consumption patterns, and are perceived as offering substantially enhanced benefits. They can be labeled radical, discontinuous, generational or breakthrough (Dahlin and Behrens, 2005). Radical innovations can also be termed disruptive, when they give rise to major transformations of entire value networks (Christensen, 1997).

Leifer *et al.*, (2003) define disruptive innovations as "a product, process or service with either unprecedented performance features or a familiar feature which offers significant improvements in performance or cost that transform existing markets or create new ones".

Radical innovation, according to Ojasalo (2008), is a new product or system with original state-of-art proprietary technology that will significantly expand the capabilities of existing ones. It requires significant R&D. Intermediate innovation is a new product with proprietary technology, however it may be duplicated by others. It is a mix of standard and special features, and requires average R&D.

However, the more radical the innovation, the more difficult it is to estimate its market acceptance and potential. According to Assink (2006) the increasing complexity and market dynamics create a substantial knowledge gap between theory and practice. As Christensen (1997) pinpoints, since the development of such innovations may take up to 20 years, or more, the future needs of customers may differ significantly from their present needs. Highly radical innovation is a unique original product or system which will obsolete existing ones. It is based on proprietary technology beyond the state-of-art and major R&D (Abetti, 2000).

Lynn *et al.* (1997) argue that in competitive, technology-intensive industries, success is achieved with discontinuous product innovations through the creation of entirely new products and businesses, whereas product line extensions and incremental improvements are necessary for maintaining leadership. However, discontinuous or radical innovations are prone to severe risks, such as the failure to gain acceptance among customers. In this regard, customer involvement in such innovations has been studied by several researchers (e.g., Martin *et al.*, 1999; Heiskanen *et al.*, 2007).

Assink (2006) views the process of disruptive innovation as a rhythm of searching and selecting, exploring and experimenting, of learning and unlearning, and cycles of divergent and convergent thinking. In other words, it is "a complex and interactive process of probing and learning or feedback". Such breakthrough innovations are based on inventions that serve as a source of many subsequent inventions (Ahuja and Lampert, 2001). These innovations, according to Assink (2006) are highly risky due to ambiguity, uncertainty, having a long development time.

Christensen (1997) believes that a single organization might not be able to pursue disruptive technology while trying to remain competitive in the market. Hence, established firms should create a spin-off firm or a completely autonomous unit to deal with this issue. However, some other researchers (e.g., Tushman and O'Reilly, 1996) are of the opinion that some organizations go *ambidextrous*; that is to say that they pursue both incremental and discontinuous innovation and changes simultaneously from hosting multiple contradictory structures, processes, and cultures within the same firm.

3.4.2 Incremental Innovations

Significant incremental innovation refers to significant extension of product characteristics with original adaptation of available technology. It is characterized with limited patent protection and minor R&D. Minor incremental innovation refers to incremental improvement over existing products. It is a standardized product and an application of current technology (Ojasalo, 2008). Incremental innovation, as Assink (2006) believes, remains within the boundaries of the existing market and technology or processes of an organization and carries lower financial and market-acceptance risks.

Many organizations limit themselves for too long to incremental innovation, such as improvements of existing designs and technologies, the so-called *dominant design* (Assink, 2006). They run the risk of being overtaken by entrepreneurial companies that introduce a disruptive innovation that totally disrupts the market (Christensen, 1997).

In his study of contingency in innovation, Drejer (1999) counts five major activities that constitute innovation management: technological integration, the process of innovation, strategic technology planning, organizational change, and business development. Leonard-Barton (1992) views innovations in the framework of core capabilities and their traditional down side that inhibits innovation, or what he calls "core rigidities". According to Lieberman and Montgomery (1988) institutionalized capabilities, may lead to "incumbent inertia" confronted with environmental changes. As Tushman and Anderson (1986) highlight, technological discontinuities can enhance or destroy existing competencies within an industry. Such shifts in the external environment resonate within the organization, so that even "seemingly minor" innovations can undermine the usefulness of deeply embedded knowledge (Henderson and Clark, 1990). In fact, all innovation necessarily requires some degree of "creative destruction" (Schumpeter, 1942).

3.5 Phases of Innovation

Abernathy and Utterback (1978) describe how a technology undergoes certain phases of its maturity. They contend that when a new technology is introduced, there are considerable uncertainties related to both the technology itself and its market. During this *fluid* phase, an introduced product might be characterized by ill-developed, unreliable, and expensive gauged against characteristics owned by an established product for a major market. According to Tidd *et al.* (2005), this phase involves extensive experimentations which come with several failures.

However, the *transitional* phase product performances are improved and therefore, the uncertainties are reduced drastically. Thereafter, a *dominant design* emerges which, according to Utterback (1994), is defined as the product "that wins the allegiance of the marketplace, the one that competitors and innovators must adhere to if they hope to command significant market following" in a product class. Moreover, this so-called transitional phase is typified by delivering product reliably, cheaply, with higher quality, and extended functionality (Tidd *et al.*, 2005).

Following the transitional phase, further incremental innovation and differentiation of the dominant design is directed to meet the needs of specific users. In this *specific* phase, process innovation is applied to reduce costs, add features, and improve productivity.

Tushman and Anderson (1986) contend that a technology evolves through periods of incremental change. This phenomenon, often termed as *technological discontinuity*, offers sharp price performance over existing technologies. They maintain that technological discontinuity might be in the forms of competence-enhancing or competence destroying. Christensen (1997) terms these specific forms as sustaining and disruptive, respectively. The competence-enhancing discontinuity is characterized by order-of-magnitude improvement in price/performance that build on existing know-how in a product class, while the competence-destroying discontinuity basically alters the set of relevant competences in a product class (Tushman and Anderson, 1986; Anderson and Tushman, 1990). Furthermore, their studies show that the competence-enhancing discontinuity is very likely initiated by established firms, whilst competence-destroying discontinuity is introduced by new entrants.

3.6 Innovation Adoption: The Technology Acceptance Model

Many authors have attempted to pinpoint the various explanatory factors which indicate the intention to use and the level of adoption of such technologies. In this regard, Rogers (1995) proposed "perceived compatibility" as a factor which reflects the degree to which the use of an innovation is considered by the individual as consistent with her values, socio-cultural beliefs and past and present experiences.

Developed in the information technology literature, the Technology Acceptance Model (TAM) portrays user acceptance of information systems (Davis, 1986; Davis, 1989). The model, shown in Figure 3-2, provides a source for tracing the impact of external factors on internal beliefs, attitudes, and intentions. The original TAM consists of perceived ease of use, perceived usefulness, attitude toward using, behavioral intention to use, and actual system use, where, *perceived usefulness* and *perceived ease of use* are the two most important determinants for system use. Also, the theory of reasoned action (TRA), proposed by Fishbein and Ajzen (1975), is a well-established model that has been used broadly to predict and explain human behavior in various domains (Chen *et al.*, 2002). Behavioral intention is the extent to which an individual intends to perform a specific behavior.

The widespread popularity of the TAM, according to Yousafzai *et al.* (2007), is broadly attributable to three factors. First, it is parsimonious, and is designed to provide an adequate explanation and prediction of a diverse user population's acceptance of a wide range of systems and technologies within varying organizational and cultural contexts and expertise levels. Second, it has a strong theoretical base and a well researched and validated inventory of psychometric measurement scales, making its use operationally appealing; and finally, it has accumulated strong empirical support for its overall explanatory power and has emerged as a pre-eminent model of user acceptance of technology.

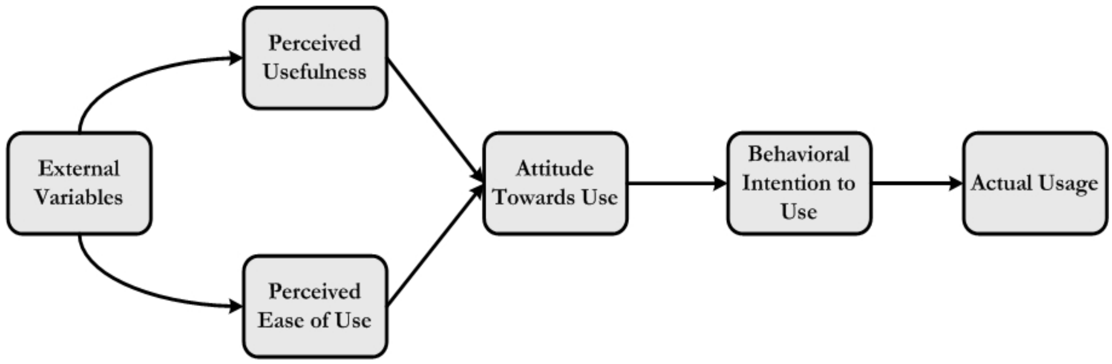


Figure 3-2 The Technology Acceptance Model developed by Davis (1986)

Many researchers suggested that TAM needed to be given additional variables to provide an even stronger model. Venkatesh and Davis (2000) proposed an extension, TAM2, which included social influence processes (subjective norm, voluntarism, and image) and cognitive instrumental processes (output quality, result demonstrability, and perceived ease of use). The supporting factors for TAM, according to Snowden *et al.* (2006), include technology complexity (involving efficiency of data transfer, functionality, interface design, and device capacity), individual preferences (prior experience of similar technologies), facilitating conditions (availability of resources and technology compatibility), social influences (views of others), and the wireless trust environment (security and privacy).

3.7 Innovativeness Levels

According to Trott (2005), there is a wide range of alternative innovation strategies which firms may follow depending on their resources, heritage, capabilities, and aspirations. In this regard, four main innovation strategies have been widely studied (e.g., Porter, 1980; Freeman, 1982; Robinson and Chiang, 2002; Tidd et al., 2005; Trott, 2005). These strategies are as follows:

- *Leader/Offensive:* The aim of such strategy is to ensure that the product is launched into the market before the competition. According to Trott (2005), this strategy demands a significant R&D activity and is usually accompanied by substantial marketing resources. Porter (1980) contends that a leadership strategy requires a strong corporate commitment to creativity and risk-taking, with close linkages both o major sources of relevant new knowledge, and to the needs and responses of customers.

- *Fast-follower/Defensive:* For such strategy the company needs to be agile in manufacturing, design and development, and marketing so as to respond quickly to those companies that are first into the market (Trott, 2005). Obviously, it requires a substantial technology base to develop improved versions of the original product, in terms of cost, design, and features. Also, according to Porter (1980), a strong commitment to competitor analysis and intelligence, reverse engineering, cost-cutting, and learning in manufacturing are of significant importance in case of a defensive strategy.

- *Cost Minimizor/Imitative:* Basically, in low-cost production, economies-of-scale comes to the fore. For such an aim, as Trott (2005) maintains, the company requires exceptional skills and capabilities in production and process engineering. Here, in comparison to the defensive strategy, the technology base is not so developed and is often licensed from other companies.

- *Market Segmentation Specialist/Traditional:* According to Trott (2005), this strategy is based on meeting the precise requirements of a particular market segment or niche; through which large-scale manufacture is not usually required and the products tend to be characterized by few product changes.

3.8 Innovation Performance Measurement

Product innovation efficacy and efficiency have been widely studied in innovation research. According to Alegre *et al.* (2006), innovation efficacy reflects the degree of success of an innovation. On the other hand, innovation efficiency reflects the effort carried out to achieve that degree of success. A study by Cooper (1988) shows that only one product concept out of seven becomes a commercial success, and only one project in four results in a winner. The same study reveals that new products face a 35% failure rate at launch.

The success of a typical product innovation program depends highly on several factors. A study by Gupta and Wilemon (1990) reveals some of these issues respectively; organizational management style, support for product innovation by top management, attention to detail in the processes of new product development (NPD), organizational strategic thinking, and manufacturing facilities to support NPD.

In a comprehensive study of NPD with a competence perspective, Craig and Hart (1992) have identified six categories of success factors; namely, management, process, company, people, strategy, and information. Jensen and Harmsen (2001) apply these success factors and Leonard-Barton's (1992) knowledge dimensions in a series of empirical case studies in the food sector. In this regard, the OECD's Oslo Manual provides a detailed measurement scale for the assessment of the economic objectives of innovation (OECD-EUROSTAT, 1997).

Also, Brown and Eisenhardt (1995) develop a model of factors affecting the success of product development that highlights the distinction between process performance and product effectiveness and the importance of agents, including team members, project leaders, senior management, customers, and suppliers, whose behavior affects these outcomes.

3.9 Summary

This chapter dealt with the concept of innovation and its significance in the survival of businesses. After a summary of innovation types, disruptive and incremental innovations were overviewed. Later on, the TAM was discussed as a model for innovation adoption. Finally, some major innovation strategies were discussed and their relations to marketing were reflected followed by some performance measurement issues in innovation. This chapter serves as a base for the next chapter on Knowledge Management where the importance of knowledge in innovation will be discussed thoroughly.

4. Knowledge-based Innovation

This chapter aims to highlight the significance of knowledge in innovation; since in this thesis patent knowledge and sales data will be applied. In this chapter a comprehensive review of the Knowledge Management literature will be provided. Later, knowledge-based innovation will be discussed where the concepts of organizational learning and knowledge integration will be discussed. Finally, the marketing perspectives of Knowledge Management will be overviewed.

4.1 Background

Post-industrial organizations today are knowledge-based and their success and survival depend on creativity, innovation, discovery and inventiveness. An effective reaction to these demands leads not only to changes, in individuals, but also to innovative changes in organizations to ensure their existence (Read, 1996). According to Devinney (1995), due to the fact that globalization is increasing the amount and diversity of information, and because management of the innovation process is almost synonymous with the management of information acquisition, it is natural that globalization is likely to lead to more opportunities for innovation.

The knowledge management literature addresses a vast number of topics such as knowledge creation, knowledge transfer, knowledge capabilities, knowledge strategy, knowledge management systems, micro-communities of knowledge or social networks of knowledge, and knowledge worker (Shani *et al.*, 2003). In this chapter, after an overview of the fundamental concepts of knowledge, the contribution of Knowledge Management to Innovation Management will be discussed.

4.2 Data, Information, and Knowledge

Data can be considered as the basis for creating information and knowledge. According to Davenport and Prusak (1998), data is a set of discrete, objective facts about events. They are represented by characters and can be produced, codified, and distributed without a reference to the context or person.

In contrast to data, *information* refers to a context. Information can be considered as messages or news created by the interpretation of data. This information can be understood by the recipient and has meaning to the recipient (Nonaka and Takeuchi, 1995). In other words, information is data within a context, where data are raw facts that can be shaped and formed to create information (Van Beveren, 2002). In a more sophisticated level, *wisdom* is assumed to bring in a deeper understanding and ethical grounds for action (Lundvall and Nielsen, 2007). According to Kakabadse *et al.* (2003)

knowing how to use information in any given context requires wisdom which is a mode of symbolic processing by a highly developed will.

Figure 4-1 depicts the knowledge creation hierarchy presented by Serban and Luan (2002).

Nonaka (1991) suggested that successful companies are those that consistently create new knowledge as solutions to unfamiliar problems, disseminate it widely throughout the organization, and quickly embody it in new technologies and products.

Knowledge is defined as "a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information" (Davenport and Prusak, 1998). According to Walters (2000), "Knowledge is neither data nor information, though it is related to both, and the differences between these terms are often a matter of degree".

Grant (1996) contends that knowledge can be considered as a resource of strategic importance; since it is scarce, relevant, costly and difficult to imitate, and difficult to transmit in some cases.

The concept of "Knowledge", according to Forcadell and Guadamillas (2002), integrates capabilities, abilities, structured information and the application of technologies which can improve products and processes, so becoming a source of competitive advantage.

In the strategic management literature, the knowledge-based view of the firm shifts the focus on the resource knowledge and proposes that knowledge is the most important resource in leverage core competencies and gaining sustainable competitive advantage (Kogut and Zander, 1992, Gold *et al.*, 2001).

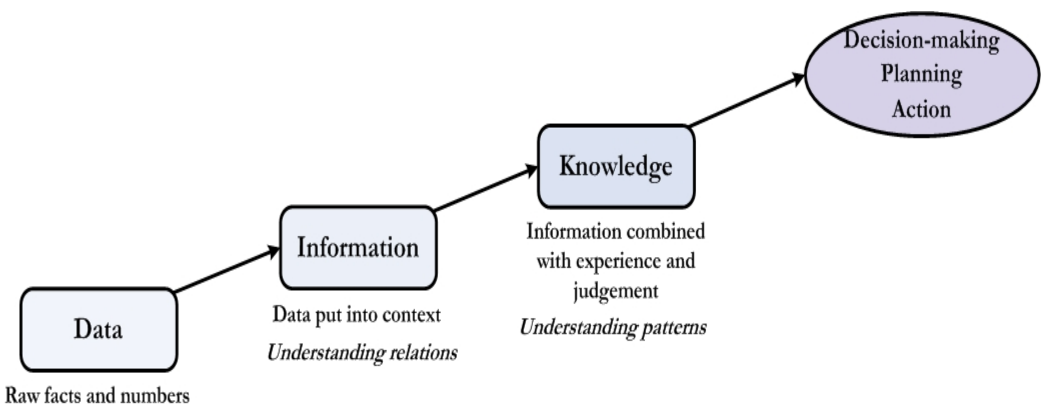


Figure 4-1 From data to knowledge
Source: Serban and Luan (2002)

4.2.1 Knowledge Types

A wide range of dimensions is used to characterize different types of knowledge (Winter, 1987). Polanyi (1962) classifies knowledge into two categories: explicit knowledge and tacit knowledge. Explicit knowledge can be codified and shared in the form of hard data, manuals, codified procedures or universal principles, while tacit knowledge results from an individual's experience and is only revealed through its application.

When knowledge can be accessed explicitly, such as in the form of language, shared meaning, or mutual cognition of the knowledge domain, it is likely more efficient for a firm to share, apply and convert the knowledge (Ju *et al.*, 2006). The more complex, tacit and systemic knowledge is, the more difficult it will be to acquire and exploit. Therefore, the lower the *complexity* of the knowledge or the higher the *modularity* and explicitness, the more firms will enhance their competences.

Nonaka and Takeuchi (1995) argue that tacit knowledge is the key to creating innovative products and services, and hence competitive advantage. They suggest that organizations innovate when individuals share their tacit knowledge, and transform this knowledge into explicit knowledge which, for example, may take the form of an idea for a product or service.

Explicit knowledge "can be articulated in formal language including grammatical statements, mathematical expressions, specifications, manuals, and so forth" while "tacit knowledge is hard to articulate with formal language. It is personal knowledge embedded in individual experience and involves intangible factors such as personal belief, perspective, and the value system" (Nonaka and Takeuchi, 1995).

Accordingly, another classification of knowledge types is:

- know-what (declarative or explicit knowledge);
- know-how (procedural or tacit knowledge);
- know-who (knowledge of individuals); and
- know-why (understanding of the context) (Nonaka and Takeuchi, 1995; Scarbrough, 2003).

According to Nonaka *et al.* (2000) there are four modes of knowledge conversion:

1. Socialization (from tacit knowledge to tacit knowledge);
2. Externalization (from tacit knowledge to explicit knowledge);
3. Combination (from explicit knowledge to explicit knowledge); and,
4. Internalization (from explicit knowledge to tacit knowledge).

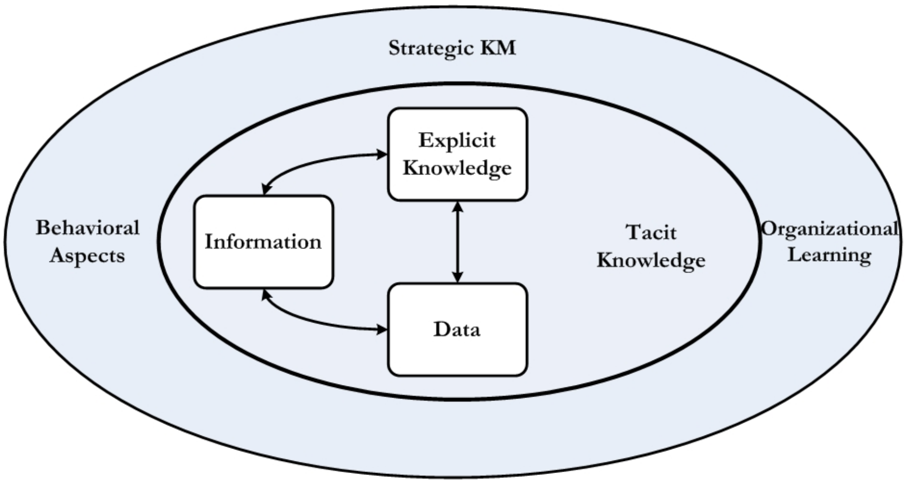


Figure 4-2 The EITS Model Paradigm
Source: Hicks et al. (2007)

Proposing the Explicit Islands In a Tacit Sea (EITS) model shown in Figure 4-2, Hicks *et al.* (2007) assimilate explicit knowledge as islands in a so-called "sea" of tacit knowledge where knowledge flows and transformations play the role of bridges between explicit systems.

4.2.2 Knowledge Characteristics

According to Cillo (2005), in the process of spreading and sharing knowledge, the key variables that influence the emergence of these bridging roles are: the complexity of the knowledge used in the innovation process and the level of cognitive distance between the contexts where knowledge is produced.

Complexity is usually defined as the increase of difficulty in comprehending how an organization functions or produces some outcomes. Tacitness is the nature of knowledge, which derives from an inability to articulate the principles that influence the performance (Ju *et al.*, 2006). Nieto and Perez-Cano (2004) point out that complex knowledge is slow to transfer and thus more difficult to apply and convert. Complexity of knowledge increases an understanding of the form that knowledge takes and the ways by which knowledge processes arise (McElroy, 2000).

Modularity preserves knowledge and creates new knowledge that enhances rather than destroys existing knowledge (Garyd and Kumaraswamy, 1995). In other words, according to Ju *et al.* (2006), modularity decomposes knowledge into specific routines that help employees implement operation activities and then promote the company's Knowledge Management capability. Similarly, the more tacit a company's knowledge, the less employees can communicate with their peers (McEvily and Chakravarthy, 2002).

Furthermore, according to Yakhlef (2005), knowledge is cumulative, i.e., it builds on previous knowledge in a sense that what we learn is often shaped by our prior knowledge. Finally, knowledge can be specific – addressing a limited number of contextual issues; or general – applied in many situations and used for solving a wide range of issues.

4.3 Knowledge Management

In many firms, Knowledge Management (KM) has become the top investment priority (Ju *et al.*, 2006). It is recognized that the performance of KM is highly associated with the intellectual capital of the firm, which in turn affects its innovation and financial achievement (Wong, 2005).

It is believed that KM promises to help companies to be faster, more efficient, or more innovative than the competition (Greiner *et al.*, 2007). According to Love *et al.* (2003) effective KM facilitates innovation, reduces project duration, and can improve both quality and customer satisfaction. Organizations that are aware of their knowledge resources possess a valuable, unique resource that is difficult to imitate and can be exploited to achieve a sustainable competitive advantage (Alavi and Leidner, 2001).

KM is understood as a process for the collection, distribution and efficient use of the knowledge resource (Davenport, 1994) that involves organization and improvement of methods, practical instruments and tools which, according to Forcadell and Guadamillas (2002), contribute to the managing of knowledge, and in a wide sense, in every area and level in the organization and which leads to improvement in products and methods of work.

Berawi and Woodhead (2005) contend that KM involves the identification and analysis of available and required knowledge, and the subsequent planning and control of actions to develop knowledge assets to fulfill the organizational objectives. *Knowledge assets* are those data related to markets, products, technologies, and organizations that a business owns or needs to own to generate profits.

McElroy (2000) pointed out the differences between what he has identified as two generations of KM. First generation KM focuses on knowledge sharing – on how to distribute existing organizational knowledge, usually through technology. In contrast, second generation KM focuses on knowledge creation – how to satisfy organizational needs for new knowledge, usually through processes of learning and value creation. In other words, first generation KM is about "imitation" (focusing on standards and benchmarks) while second generation KM is about "innovation". Following McElroy's line of thought, Laszlo and Laszlo (2002) propose a third generation of KM which deals with democratization of knowledge, citizen involvement, and the expansion of the boundaries of what has been considered education in order to design an authentic learning society. Figure 4-3 depicts the mentioned generations of KM.

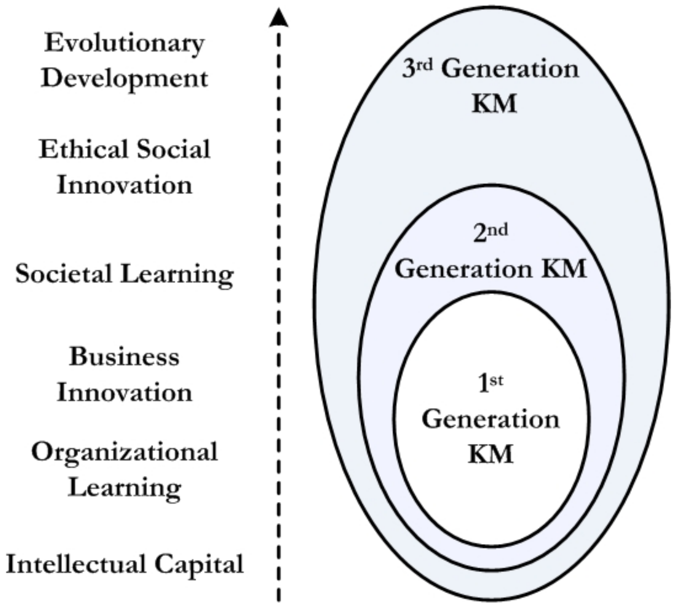


Figure 4-3 Evolving KM
Source: Laszlo and Laszlo (2002)

Trott (2005, p. 289) contends that technical knowledge – in the form of "patents" – or commercial knowledge – in the form of "unique channels of distribution" – are available to other firms as well.

The KM strategy is understood, within a resource-based view of the firm, as an overall change process and a form of organizational renewal, focused on innovation, through the creation, transmission and application of new knowledge (Cohen and Levinthal, 1990). According to Kogut and Zander (1992), the implementation of a KM strategy allows improvement of the firm's learning capability and its ability to combine knowledge-based capabilities and so make better use of them.

4.4 Knowledge Management and Innovation

KM has received an unprecedented level of attention as a prominent phenomenon that leads to innovation and competitiveness (Leonard and Sensiper, 1998; Darroch, 2003; Lundvall and Nielsen, 2007).

Leonard-Barton (1992) adopts a knowledge-based view of the firm and views a core capability as the knowledge set that distinguishes and provides a firm with competitive advantage. His knowledge-set consists of four different knowledge dimensions: *employee knowledge and skills* and embedded in *technical systems*. The processes of knowledge creation and control are guided by *managerial systems*. The fourth dimension is the *values and norms* associated with the various types of embodied and embedded knowledge and with the processes of knowledge creation and control.

In this section, the relation of the concept of KM to Innovation Management will be discussed.

4.4.1 Background

The innovative efforts include the search for, discovery, experimentation, and development of new technologies, new products and/or services, new production processes, and new organizational structures (Carneiro, 2000). Scholars of innovation have argued that novel innovations often result from combination of existing pieces of knowledge (Schumpeter, 1934; Utterback, 1994; Tidd *et al.*, 2005). A knowledge-based view of the firm emphasizes that a firm's accumulated knowledge is key to its continued ability to innovate, and ultimately to its ability to compete. Therefore, having a diverse knowledge base within the firm can facilitate innovation through novel combinations of readily accessible pieces of knowledge (Seidler-de Alwis and Hartmann, 2008; Singh, 2008).

In this regard, KM has emerged as the most recent phenomenon that promises to lead to innovation and competitiveness (Leonard and Sensiper, 1998). According to Fischer (2001), Innovation and knowledge creation are viewed as interactive and cumulative processes contingent on the institutional set-up. Lundvall and Nielsen, (2007) believe that a striking characteristic of knowledge production resulting in innovation is that knowledge, in terms of skills and competencies may be perceived as *the* most important input. Moreover, a comprehensive empirical study by Darroch (2003) shows that firms that effectively manage knowledge are likely to be more innovative and perform better.

4.4.2 KM Implementation in Innovation

The process of implementation of a KM strategy involves the operations of creation, storage, distribution and application of knowledge. It is remarkable how this cycle, especially the creation of knowledge, is closely related to innovation. The creation of new knowledge and of innovations implies the application of intelligence, tacit knowledge and information: that is, an interaction between actions and behaviors.

The action of creation does not consist of the processing of information or data, since the obtaining of tacit knowledge, which cannot be directly processed, is a fundamental part of this phase. It allows for the development of improvements and innovations on products and processes, capable of creating value, which then become part of the new knowledge in the system (Forcadell and Guadamillas, 2002). In addition, it is important to consider a number of aspects in the knowledge-creation process; namely, the organization's internal knowledge base; the acquisition of information and knowledge from external sources; the integration of internal and external knowledge and its application to problem solving; the creation of new knowledge and the generation of innovations from this integration, and finally the importance of the organization's capacity to absorb new knowledge.

In a comprehensive study of knowledge projects and their connection to organizational innovation, Braganza *et al.* (1999) contend that knowledge projects should be very clearly linked to the strategic intent of the organization, and that they should be managed according to their intended contribution. Respectively, they propose two phases:

Phase 1: Determine the purpose of the knowledge project.
Phase 2: Classify and manage the knowledge project based upon the contribution to innovation.
Later, they propose a knowledge-innovation diamond, depicted in Figure 4-4, which classifies knowledge projects based on the intended benefits.

In the *explore* domain, organizations locate knowledge projects whose purpose are to create and test knowledge-enabled innovations that are new to the organization *and* the industry in which it operates. These projects exist with the sole intention of proving competitive benefits are available from the innovation. Knowledge projects in the *explore* domain lead to the identification of innovations that fundamentally alter the basis of competition or make an order of magnitude improvement in the existing basis of competition in the industry. This domain is characterized by a period of discovery during which time a deeper understanding of current knowledge and its potential for innovation is established. Organizations embarking on a search for innovation are unlikely to know in advance which knowledge projects will lead to innovation. Hence, organizations face a high degree of uncertainty in terms of the ultimate contribution to innovation of knowledge projects in this domain.

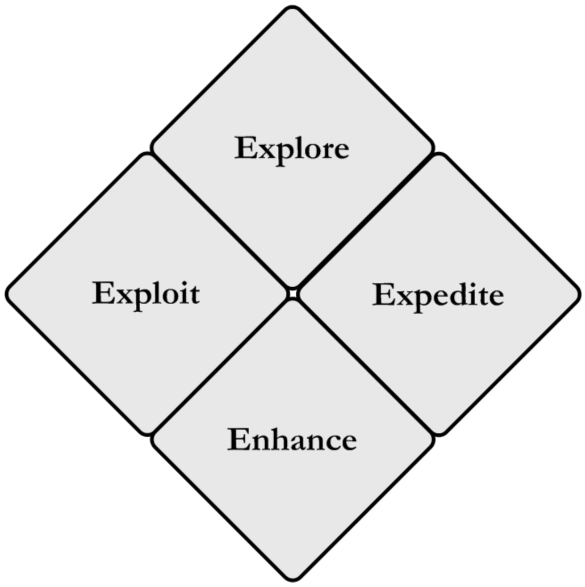


Figure 4-4 The Knowledge-Innovation Diamond
Source: Braganza et al. (1999)

In the *exploit* domain, organizations locate knowledge projects whose purpose is to *deliver* significant innovations. These innovations fundamentally alter the basis of competition or make an order of magnitude improvement in the existing basis of competition in the organization's chosen industry. These innovations contribute directly to the achievement of the organization's strategic intent. This domain is characterized by a period of development and roll-out, during which time the innovation is introduced to provide the organization with superior competitiveness.

Organizations locate knowledge projects, in the *enhance* domain, when their purpose is to improve existing performance so that the organization maintains current competitiveness. Knowledge projects in this domain ensure current operations remain in line with developments in the industry. These projects do not lead to the creation or identification of new industry innovations, instead they ensure the organization's competitiveness is sustained. Knowledge projects are located in the *expedite* domain, whose purpose is to improve localized efficiency and avoid cost increases in the longer term. This domain is characterized by small projects each of which is useful in their own right but do not directly support the business strategy of the organization (Braganza *et al.*, 1999).

4.4.3 Knowledge Innovation

Amidon (1997) defines Knowledge Innovation (KI) as "The creation, evolution, exchange and application of new ideas into marketable goods and services, leading to the success of an enterprise, the vitality of a nation's economy and the advancement of society".

According to Goh (2005), two key elements are important in the definition. First, it recognizes that knowledge is the core component of innovation – not technology or finances. Second, the actions associated with managing the flow and use of knowledge in an innovation process is another core component. He further proposes a model for the potential integration of Innovation Management and KM that would shape how businesses compete in the future. This model is illustrated in Figure 4-5.

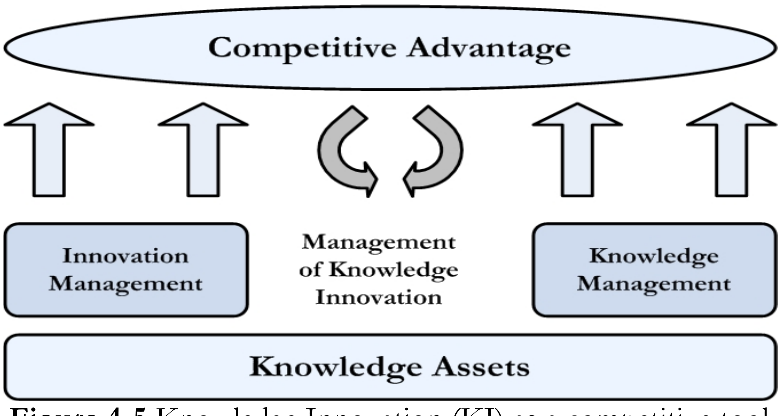


Figure 4-5 Knowledge Innovation (KI) as a competitive tool
Source: Goh (2005)

To summarize, three main drivers of KM in innovation are:

- To create, build, and maintain competitive advantage through utilization of knowledge and through collaborative practices.
- To use knowledge as a resource to reduce complexity in the innovation process.
- To integrate knowledge, both internal and external, to the organization; and thus, make it more available and accessible (Du Plessis, 2007).

4.5 Organizational Learning and Innovation

According to Hart *et al.* (1999), the organizational learning literature has contributed to Innovation Management and posits that market information processing is a function of what the organization has learned previously, in terms of both facts about its relevant markets and its particular way of acquiring, distributing, interpreting and storing information, whether that be formal or informal. Moreover, several authors have studied the impact of organizational culture as a contributing factor on the level of innovation in an organization (Tushman and O'Reilly, 1997; Martins and Teblanche, 2003).

Knowledge is the key that combines organizational learning and innovative activities and hence strengthens a firm's competitive advantage. Firms must ensure continuous organizational learning and maintain a superior internal KM system (Ju *et al.*, 2006). In this regard, according to (Rowley, 2000), organizational learning, which according to Ju *et al.* (2006) is hard to achieve, is intimately associated with survival and future success.

Innovation studies have emphasized the extent to which innovation process involve the integration of external knowledge with the existing organization (Leonard-Barton, 1995; Wu *et al.*, 2002). Mullen and Lyles (1993) suggest that continuous organizational learning improves the efficiency and effectiveness of a firm’s innovation.

Discussing the significance of vision-based leadership in gaining sustainable competitive advantage through innovation, Rebernik and Širec (2007) propose a multidimensional model, shown in Figure 4-6, which entails organizational learning in different levels; namely, individual, organizational, and environmental. They maintain that these three levels have a number of factors considered to be parallel.

Similarly, Liao *et al.* (2008) count two main types of organizational learning: (1) *Exploitative* learning which is the acquisition of new behavioral capacities framed within existing insights. Exploitative learning has also been described in the literature as *single-loop*, *operational*, *first-order*, *evolutional*, *frame-taking*, *reactive*, and *incremental*. (2) *Explorative* learning which occurs when organizations acquire behavioral capacities that differ fundamentally from existing insights. Exploration is about discovery, variation, effectiveness, flexibility and innovation. This type of organizational learning is also referred to as *double-loop*, *strategic*, *second-order*, *revolutionary*, *frame-breaking*, *proactive*, and *radical*.

According to Senge (1990), learning organizations have the following five disciplines in common; namely, Systems thinking; Personal mastery; Mental models; Building shared vision; and, Team learning.

Moreover, in the context of sustainable development, Siebenhüner and Arnold (2007) define sustainability-oriented learning as "the process where organizations display behavioral changes that attributable to a change in the knowledge and value base as a result of reflexive process, and where the concept of sustainability served as a fundamental framework".

4.6 Knowledge Integration

Solutions to complex innovation problems often require integration and synthesis of diverse, complementary knowledge. Tiwana (2008) defines knowledge integration as "the process of jointly applying specialized knowledge held by various alliance partners at the project level".

He also argues that prior research has conceptualized knowledge integration in two different ways; namely, as across individuals in different, dispersed groups; and, as integration of different streams of knowledge.

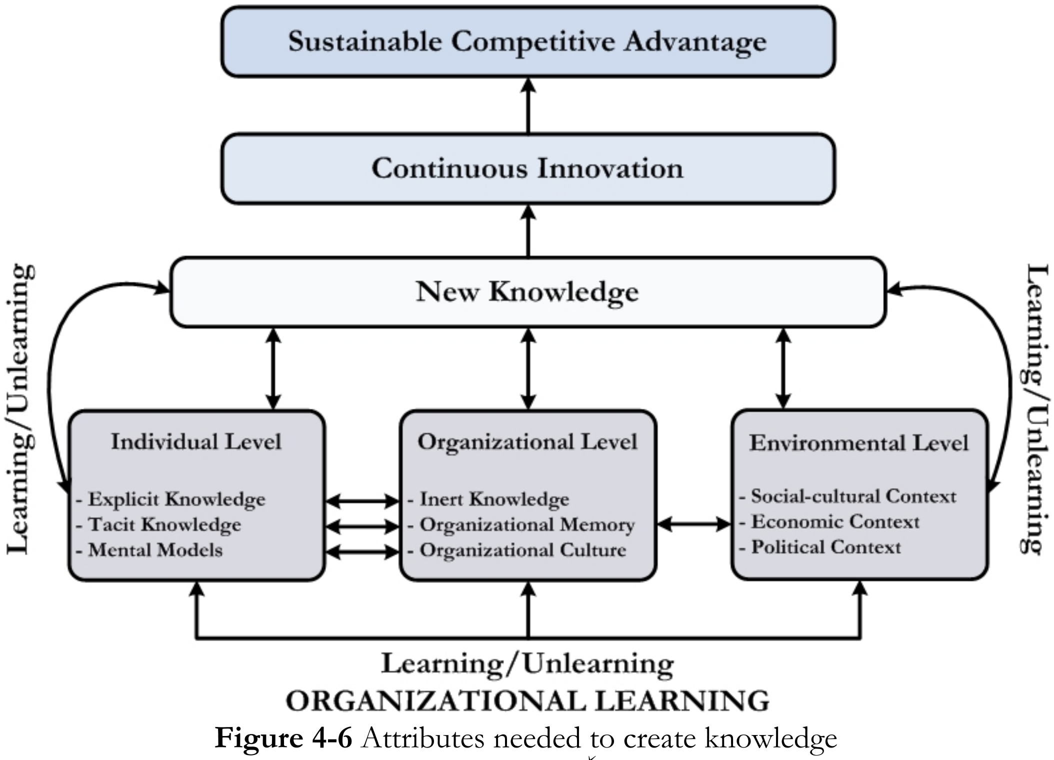


Figure 4-6 Attributes needed to create knowledge
Source: Rebernik and Širec (2007)

Several processes have been used by firms to synthesize their experience and integrate it with knowledge. Knowledge integration helps the firm create conditions under which multiple employees can integrate their knowledge through systems or communication. However, integration has been viewed as dependent upon the characteristics of the knowledge or technology manipulated (Soliman and Youssef, 2003). Therefore, Grant (1996) proposed the following mechanisms for knowledge integration; rules and directives, sequencing, routines, and group problem-solving and decision-making

Janczak (2002) analyzed the process model of knowledge integration within the organization into three stages: 1) awareness, 2) exploring versus exploiting knowledge, and 3) codifying and assessing results.

In the knowledge integration and technology innovation process, engineering experimentation plays a fundamental and significant role at the firm level (Hung *et al.*, 2007). As described by Thomke *et al.* (1998), the general nature of the trial-and-error problem-solving process and strategies of experimentation are significant for NPD. The rapid progress being made in problem-solving methods and the impact on such progress could improve the competitive position of adopting firms. West and Iansiti (2003) argued that two organizational mechanisms support innovation and retention of knowledge: experience and experimentation. He also established the correlation of the use of these mechanisms with R&D performance.

4.7 KM and Marketing

According to Popadiuk and Choo (2007), both forms of knowledge creation – exploration through the socialization and externalization of tacit knowledge, and exploitation through the combination and internalization of explicit knowledge – take place in a context where the use of this knowledge is given meaning and significance. They further contend that considering innovation by firms, the relevant context is the market, since innovations are defined as new ideas that have been commercialized as products or implemented as processes. Thus, in addition to knowledge creation, the other knowledge-based dimension is the organization's knowledge about its market.

In the realm of innovation, three main classes of knowledge have proven to be of crucial importance, namely, knowledge about users, knowledge about technological opportunities, and knowledge about product languages. In this regard, according to Dell'Era *et al.* (2008), the main concern in knowledge management approaches is the relative importance of these classes. A technology-push approach is driven by technological needs, a market-pull approach is driven by user needs, and finally, in the case of a design-push strategy the driver of innovation is the capability to understand, anticipate, and influence the emergence of new product meanings in the market.

The body of literature on the source of innovation ideas maintains that customers, or direct contact with customers, play an important role for generating R&D ideas. As sustainable innovations often require changes in user behavior, it is important to identify key factors facilitating and obstructing their adoption (Heiskanen *et al.*, 2005). Through the involvement of consumers in product development, different knowledge bases can be combined. The contextual everyday knowledge of product users, in combination with the technical knowledge of companies, may lead to mutual learning, technical innovations and changes in production and consumption patterns (Hoffmann, 2007). In this regard, Li and Cavusgil (1999) define market knowledge competence in NPD as a multidimensional structure comprising three processes that generate and integrate market knowledge; namely, learning about customers; learning about competitors; and the marketing-R&D interface.

A basic premise has, therefore, been included in the creation of knowledge: that a firm needs to continuously renovate its knowledge base to ensure that the base does not become obsolete for the development of innovations. New knowledge, the basis for innovation, will constitute the future knowledge base for the organization and will contribute to the regeneration and widening of the existing base (Forcadell and Guadamillas, 2002).

4.8 Summary

In this chapter, first, the concept of knowledge was overviewed; then in a comprehensive study of the literature on KM, the importance of KM in Innovation Management was highlighted. Moreover, the significance of learning organizations and knowledge integration were discussed. Finally, some marketing applications of KM were provided in the final segment. The reason why a separate chapter was dedicated to KM is that in the empirical study section of the thesis, patent knowledge and sales data were applied for further analysis. Hence, the importance of KM as a cornerstone subject in Innovation Management needed to be spotlighted. The next section of the thesis deals with the empirical study; wherein, after a review of research method techniques, the patent study will be carried out. With the application of the theoretical framework provided in Section I, the results of the studies in Section II will be analyzed in Section III.

Section II

EMPIRICAL RESEARCH

5. Research Method

This chapter is presented to illustrate the reader with the scientific methods that were practiced in the development of the thesis by concepts and procedures. It describes the idea of how to perform the scientific approach with the tools collected by the empirical data, and how the empirical part of the thesis will be executed;

5.1 Research Purpose

Methodology is used as a tool by which we solve problems and create new knowledge. It provides route signs for undertaking a research process as well as helping authors to write the project report. Generally, two major scientific types of approaches are known for research conduction: the *positivistic* approach, which establishes consistent scientific facts and *hermeneutic* approach, which interprets the subjective drawing to the research topic.

Research is defined as a systematic investigation to find answers to a problem. The purpose of research, according to Wiedersheim-Paul and Eriksson (2000), is a statement of what is to be accomplished by conducting research and how the results of the research can be used. According to Yin (1994), research can be classified as exploratory, descriptive or explanatory. Below, these different classifications will be discussed briefly.

5.1.1 Exploratory Studies

Exploratory studies are a valuable means of finding out "*what is happening*", to seek new insights, to ask questions and to assess phenomena in a new light (Saunders *et al.*, 2000). This type of research is suitable when a problem is difficult to demarcate, and there is not a clear apprehension about what sort of model should be used and which characteristics and relations are important (Wiedersheim-Paul and Eriksson, 2000). According to Yin (1994), an explanatory study is used when we aim at developing propositions for future research. Exploratory research can be conducted in three ways:

- A research of the literature;
- Talking to experts in the subject; and
- Conducting focus group interviews.

5.1.2 Descriptive Studies

Descriptive research is often applied in case the problem is well-structured and there is no intention to investigate cause/effect relations. According to Yin (1994), descriptive studies are used when the characteristics of interests are investigated in a situation offering a profile of describing relevant aspects of a phenomenon.

5.1.3 Explanatory Studies

According to Saunders *et al.* (2000), studies that are used to establish causal relationships between variables may be termed explanatory studies. An explanatory study tries to identify cause-and-effect relationships between variables.

This thesis aims at gaining a better understanding of how automotive manufacturing companies can manage their technological innovations programs within power trains. Meanwhile, it studies the relationship between their sustainability and Knowledge Management strategies can influence innovation policies. Therefore, this study is both descriptive and explanatory in nature.

5.2 Research Approach

There are several techniques to conduct a research but generally the nature of the investigation determines the research approach of a study, which can be either theoretical or methodological. The theoretical approach can be inductive or deductive, and the methodological approach is qualitative or quantitative. Below, these approaches are presented in brief.

5.2.1 Inductive and Deductive Research

Inductive reasoning is a theory-building process, starting with observations of specific instances, and seeking to establish generalizations about the phenomenon under investigation. As Yin (1994) mentions, an inductive research implies that general conclusions are drawn from empirical findings. Deductive reasoning is a theory process which starts with an established theory or generalization, and seeks to see if the theory applies to specific instances. In this type of reasoning, several hypotheses are constructed from existing theory and are then tested in reality (Wiedersheim-Paul and Eriksson, 2000).

This study is classified as "inductive" since some general conclusions are drawn from empirical findings from the patent study.

5.2.2 Qualitative and Quantitative Research

Generally, two main theories of research methods are recognized: *qualitative* and *quantitative*.

Qualitative research is recognized as a method where an in-depth approach to the subject is conducted with the purpose of reflecting an increased understanding of the problem as a whole. Qualitative methods are often related to case studies and thorough studies where the objective is to access a lot of information from few units.

Quantitative method, often thought of as the polar opposite to the qualitative method, is a research method that relies on analysis of numerical data, figures and statistical analysis (Easterby-Smith *et al.*, 2002). It is a method of involving numerical and statistical variables over the bridge of data collection procedures. In a quantitative research, a large number of objects are selected and studied in order to increase the ability to draw general conclusions (Yin, 1994). Such methods are often used to explain causal relationships, to facilitate generalization, and also to predict the future. However, qualitative and quantitative approaches are to a great extent complementary. According to Eisenhardt (1989), the empirical evidence of a case study may be qualitative, quantitative, or both.

Since this thesis aims at studying how technological innovation policies are shaped and is based on analysis of patent data, it can be considered as having a quantitative approach. Also, since it focuses on the automotive industry as an experimental case study, it has a qualitative track as well.

5.2.3 Literature Search

After defining a domain for research and outlining the relative necessary methodologies, a search for relevant literature was performed. In order to find pertinent literature, different databases have been used, including In Emerald, Elsevier, John Wiley, Ebesco and Springer, which are all available on KTH Biblioteket website.

Some of the keywords used for searching for information and literature were: "*Innovation*", "*Corporate Social Responsibility*", "*Marketing Management*", "*Sustainable Management*", "*Technology Acceptance*", "*Automotive Industry*", "*Strategic Management*", "*Engine Technology*", and etc. These words were combined in different ways in order to maximize the number of hits.

The "Literature Review" of this thesis is basically provided in the first section – chapters 2 to 4 – where the concepts of Sustainability and Corporate Social Responsibility, Innovation Management, and Knowledge Management are covered.

5.3 Research Strategy

According to Yin (1994), qualitative research can be conducted using several approaches, including experiments, surveys, histories, analysis of archival information and/or case studies. The selection of strategy depends upon three distinct conditions. The following conditions should determine which strategy is appropriate:

- The type of research questions posed
- The control an investigator has over actual behavioral events
- The degree of focus on contemporary events compared to historical phenomenon.

Table 5-1 illustrates the mentioned strategies and their corresponding research questions.

Table 5-1 Relevant Situations for Different Research Strategies

Strategy	**Form of research question**	**Requires control over behavioral events?**	**Focus on contemporary events?**
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival Analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case Study	How, Why	No	Yes

Source: Yin (1994), p. 6

Since this thesis deals with analysis of patent and sales data, it could be classified as "archival analysis" and "history". Also, as far as it is focused on the automotive industry, and "how" and "why" automotive companies manage innovation in the powertrain, it could be labeled as a "case study". Moreover, the analysis and the theoretical framework sections of the thesis give it a theme of a "survey" as well.

5.4 Data Collection Methods

According to Wiedersheim-Paul and Eriksson (2001), there are two categories of collecting data, namely primary and secondary. Primary data is collected for a specific purpose by the researcher and the information is gathered for instance through interviews, questionnaires and observations. In this thesis the primary data was collected through patent studies. Secondary data is the data that already has been collected for another purpose and the information can be obtained from instance books, articles and research reports. In this study the chapters regarding the theoretical framework are of secondary nature.

According to Yin (1994), case studies can be based on six different sources of evidence: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts. Table 5-2 summarizes the strengths and weaknesses of the different sources of evidence.

Table 5-2 Data Collection Methods: Strengths and Weaknesses

Source of evidence	Strengths	Weaknesses
Documentation	Stable: can be reviewed repeatedly Unobtrusive: not created as a result of the case Exact: contains exact names, references and details of an event Broad coverage: long span of time, many events and many settings	Retrievability: can be low Biased selectivity: if collection is incomplete Reporting bias: reflects (unknown) bias of author Access: may be deliberately blocked
Archival Records	Same as above for documentation Precise and quantitative	Same as above for documentation Accessibility due to privacy reasons
Interviews	Targeted: focuses directly on case study topic Insightful: provides perceived casual inferences	Bias due to poorly constructed questionnaires Response bias Inaccuracies due to poor recall Reflexivity: interviewee gives what interviewer wants to hear
Direct Observation	Reality: covers events in real time Contextual: covers context of event	Time consuming Selectivity: unless broad coverage Reflexivity: event may proceed differently because it is observed Cost: hours need by human observers
Participant Observation	Same for direct observations Insightful into interpersonal behavior and motives	Same as for direct observations Bias due to investigator's manipulation of events
Physical Artifacts	Insightful into cultural features Insightful into technical operations	Selectivity Availability

Source: Yin, 1994, p. 80

In this study, "Documentation" and "Archival Records" were selected as the data collection methods in the patent study. The patent study in part 6.2 is based on the information extracted from The European Patent Office database website[1]. As far as archival records are more suitable in the case of quantitative approaches, they were used in the sales study section. Also direct and participant observations were not applicable in this case. The physical artifacts were also excluded because this study is not focused on cultural features or technical operations.

[1] www.espacenet.com

5.5 Data Analysis

Perhaps the most crucial aspect of a research is the analysis of the data. As Yin (1994) highlights, data analysis implies examining, categorizing, tabulating or otherwise recombining the collected data, and can be classified as within-case and/or cross-analysis. According to Miles and Huberman (1994), data analysis could be divided into three stages; namely,

1. *Data Reduction*: The process of selecting, focusing simplifying, abstracting, and transforming the data. The purpose here is to organize the data so that final conclusions can be drawn and verified.
2. *Data Display*: Taking the reduced data and displaying them in and organized, compressed way so that conclusions can be easily drawn.
3. *Conclusion Drawing/Verification*: Deciding what things mean; i.e., noting regularities, patterns, explanations, possible configuration, casual flows, and propositions.

In this thesis the patent data and sales statistics of different automotive manufacturers are studied and compared against one another. Here, the three mentioned stages of data analysis could be obviously recognized. First the relevant patent data is selected and extracted. Then, the necessary data is tabulated and graphed, and finally, some patterns and regularizes are extracted taking into consideration the sales and innovation policies.

5.6 Patent Analysis

The patent system was initially designed to provide incentives to develop stand-alone innovations in fields such as mechanics, chemicals or pharmaceuticals. Its application is therefore problematical in more recent fields where innovation patterns are different (Ménière, 2007).

Patent analysis has become increasingly popular in studying R&D behavior of firms, industries and counties. Patent study illustrates how technological preferences have shifted over time (Van den Hoed, 2007) and is a valuable source of information that can be used to plot the evolution of technologies (Pilkington and Dyerson, 2006).

As Ma and Lee (2007) highlight, patent statistics is used as measure of inventive activities' output, innovative activity, technological change, technological strength, accumulated capabilities, and specialization in many industries, and thus is widely accepted. Patent statistics is publicly available, remains up-to-dated, and provides very specific and detailed information for tracing inventive activities over time. Furthermore, patent statistics is the only formally and publicly verified output measure of inventive activities.

For these reasons, researchers have begun to favor patent statistics and use it exclusively as the measures of innovation and inventive activities.

Scholars have also tried to infer the impact of patenting on innovation by examining the relationship between either patenting activity or patent strength, and measures of innovation or innovative activity – usually R&D or sometimes patenting itself (Park and Ginarte, 1997; Kanwar and Evenson, 2003). These analyses have been conducted variously with time series or cross-sectional data (Arora *et al.*, 2008).

According to Ma and Lee (2007), given the "non-linear" nature of innovation and inventive activities, researchers in these fields must be cautious of at least three issues in selecting appropriate databases for study:

- the lumpy nature of inventive activities,
- the interactions between various component of these activities over time, and
- the uneven distribution over time and representativeness of selected activities.

They further contend that patent statistics from a reasonably long time-series will be able to resolve the first two problems, while the other (the unevenness and representativeness) may need explicit remedies.

In this thesis, therefore, patent analysis was chosen to study the innovative activities in the automotive industry. Thereafter, this work tries to find the possible links between the innovativeness of automotive companies, the amount of their registered patents, their sales data, and their sustainability policies. Hence, it will show how companies can manage patent knowledge to help their innovation strategies. Also, in order to prevent the aforementioned concerns linked to the non-linearity of innovation activities, a time span of 17 years – from 1990 to 2007 – was chosen for the patent analysis. The patent search was done in the European Patent Office database.

5.7 Summary

This chapter dealt with the issue of research method, and how research purpose, approach, and strategy should be defined. In this regard, exploratory, descriptive, and explanatory studies, inductive/deductive, and qualitative/quantitative approaches were overviewed. Further on, various data collection and analysis methods were described, and finally, the importance of patent analysis – which is a main tool in this thesis – in innovation management is highlighted.

A summary of the research methodology used in this thesis is illustrated in Figure 5-1.

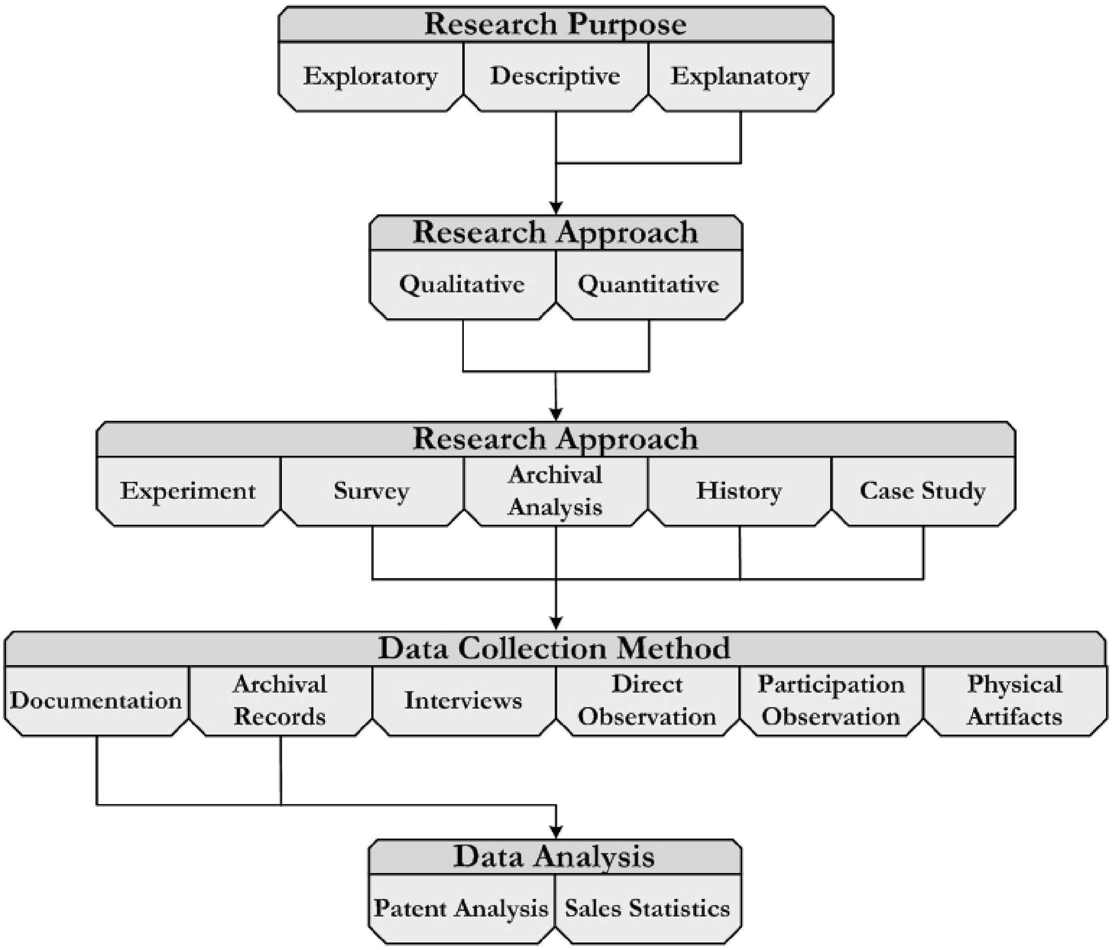


Figure 5-1 Graphical Presentation of Research Methodology

6. Empirical Study

In this chapter, the major technological innovations in the automotive industry will be reviewed. These radical or incremental innovations are basically in the powertrain and body; however, here, the main focus will be on the powertrain of vehicles and the connections with sustainability. In this regard, after an overview of the contemporary, developed, and emerging technologies, a study of the issued patents in Europe regarding the two major technologies in the field – hybrid and battery electric – will be carried out.

6.1 Innovation in the Automotive Industry

The automotive industry is not always associated with radical innovation. Complex operations, low margins, and high risks tend to favor more incremental and more process oriented innovations. Radical technology adoption is rare as it requires major shifts in competencies and automotive operations. Since the late 1960s the automotive industry has faced increasingly stringent regulations, most notably related to local emissions (NO_X, CO, VOC), fossil fuel use, and in more recent years greenhouse gases (CO_2). Table 6-1 shows the EU emission limits for light vehicles for the coming years. Most standards set by governments could be met with improved versions of the current ICE or other measures such as developing lightweight constructions or integrating catalyst technologies. This changed in 1990, when the California Air Resources Board (CARB) issued the so-called Zero Emission Vehicles (ZEV) regulation (Van den Hoed, 2007). Also, dominant market demands in the auto industry have been relatively stable over the last decade, and are mostly related to cost, safety, comfort and environment (Wells and Nieuwenhuis, 2001).

Table 6-1 EU Emission Limits for Light-duty Diesel Vehicles, NEDC (New European Drive Cycle) [g/km][1]

Class	From Year	CO	HC	HC + NO_X	NO_X	PM
Euro 4	2005	0.30		0.30	0.250	0.025
Euro 5[2]	2008-10	1.0	0.075		0.18	0.005
Euro 6[2]	2014	tbd	tbd		0.07	tbd

[1] Press release by ACEA, 7 February 2007.

[2] European Parliament's Environmental Committee (EPEC) proposal

Romm (2006) counts six major barriers to Alternative-Fuel Vehicle (AFV) success; namely;

1. high first cost for vehicle
2. on-board fuel storage issues (i.e., limited range)
3. safety and liability concerns
4. high fueling cost (compared to gasoline)
5. limited fuel stations
6. improvements in the competition (better, cleaner gasoline vehicles).

As depicted in Figure 6-1, the innovation in the engine technology is involved with 50 % in the emission reduction. Beside the engine technology, lightweight construction, aerodynamics and reduction in rolling friction are main players in the major innovations strategies regarding emission reduction today.

This shows the significance of engine technologies in the automotive industry. Hence, this study is focused on this sector.

6.1.1 Major Technological Innovations in the Power-train[3]

A range of engine technologies is available to improve vehicle performance and better designs exist that allow increased capacities, as well as improved durability and longer service-lives. Here, the main such technologies will be discussed briefly.

i. Diesel Technologies

Diesel engines are recognized and favored worldwide for their fuel efficiency, excellent durability and low maintenance requirements. They offer the convenience of using a liquid fuel that is easily dispensed through an established fueling infrastructure. The technology is mature, widely-produced and competitively priced. Although diesel engines have historically produced high levels of pollutant emissions, especially oxides of nitrogen and control technology have resulted in new diesel systems for vehicles that are substantially cleaner than they were a few years ago.

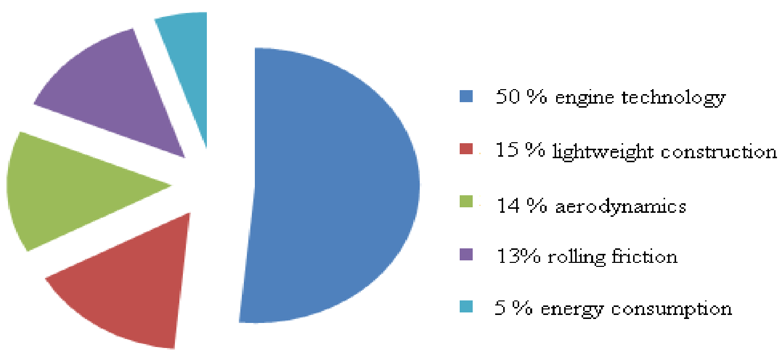


Figure 6-1 Innovation in different vehicle sectors
Source: Based on (Goede, 2007)

[3] The non-cited technical information in this part are derived from IEA (2002, pp. 61-119).

Diesel exhaust remains a major concern in most countries, particularly emissions of fine particulates, oxides of nitrogen (NO_X) and toxic hydrocarbons. In developing countries, particulate matter (PM) of all sizes is often a major concern, and diesel vehicles are often a major source. Other problems with diesel exhaust are the volatile organic compounds (VOCs) that are present as solid and gaseous matter.

Due to the growing concern around the world over vehicle emissions, diesel fuel is at the same turning point that gasoline was in the late 1980s, when regulators sought drastic reductions in emissions from gasoline-powered vehicles. Eventually, these reductions were achieved through a combination of reformulated gasoline, improved engine design and, most importantly, advanced exhaust after-treatment systems featuring improved catalytic converters. This has allowed gasoline-powered vehicles to meet the same tight emissions standards in the US and Europe as "inherently clean" alternative-fuel vehicles, such as those running on compressed natural gas (CNG).

ii. Biodiesel and Blends

Biodiesel is an ester-based oxygenated diesel fuel made from vegetable oil or animal fats. It can be produced from oilseed plants or used vegetable oils. It has similar properties to petroleum-based diesel fuel and can be blended into it at any ratio for use with conventional diesel engines. It is most often blended into petroleum-based diesel fuel at 20% which is referred to as “B20” and has about 30% less particulates and almost 50% reductios in hydrocarbon emissions than conventional diesel. However, it has not proven to have so much NO_X reduction.

Moreover, biodiesel blends are quite expensive relative to some other options like ultra-low-solphur-diesel (ULSD).

iii. Compressed Natural Gas (CNG)

Recently, there ahs been a great interest in applying natural gas in conventional vehicles powered by slightly modifies internal combustion engines. Natural gas is a simple hydrocarbon fossil fuel that typically contains up to 99% methane (CH_4) and near-zero sulphur. It is naturally clean-burning, and in many countries relatively abundant and inexpensive. Furthermore, over the long term, natural gas may also be a bridge to advanced technologies utilizing gaseous fuels such as hydrogen fuel cells. However, CNG has some shortcomings as a vehicle fuel. Due to the very low energy density of methane, the gas must be compressed for on-board storage in large, expensive cylinders, weighing as much as several pounds.

iv. Liquefied Petroleum Gas (LPG)

LPG is a mixture of hydrocarbons including propane, ethane and butane, that are in gas phase at ambient conditions but liquefy under moderate pressure. LPG is in some ways similar to CNG but offers some advantages in terms of performance, cost, and range. Few important obstacles confront the successful commercialization of LPG as a motor fuel apart from the willingness of manufacturers to produce LPG vehicles.

v. Hybrid-electric-drive Systems

A hybrid is defined as carrying at least two sources of motive energy on board and using electric drive to provide partial or complete drive power to the vehicle wheels. The hybrid-electric technology is not fuel-specific, and hybrid applications have been tested using mature engine technologies and diesel, CNG and propane fuels. In a series hybrid, only the electric motor drives the wheels and the engine provides electrical energy to the motor. In a parallel hybrid, the electric motor and engine are both connected to the wheels and can both power the vehicle.

From a strategic management point of view, in the case of hybrid cars, it was Toyota who took the *fist-to-market* approach by launching a mass-produced gasoline electric hybrid Prius in 1997. The launch was very well publicized but received no followers among other firms. However, Toyota, the pioneer in *lean manufacturing*, continued the production of the car and publicized itself as *the* green car producer. This issue will be addressed later.

There are in principle many different types of hybrids. Various drive-system configurations are possible and the drive-train power can be divided between the combustion engine part and the electric motor/battery part in any proportion. Furthermore, some types of hybrid vehicles, known as plug-in hybrids would have larger battery packs and a substantial range of operation on battery/motor power alone (Lipman and Delucchi, 2006).

Hybrid drive offers numerous operational advantages over conventional drives, such as smoother and quicker acceleration, more efficient braking, improved fuel economy and reduced emissions. Hybrids can be used on just about any duty cycle; however, regular use on high-speed express routes or hills may require design or control optimization. Due to the complexity of the combined mechanical and electric-drive systems, maintenance requirements may be higher than for conventional vehicles, at least until the technology matures. Mechanical and safety retraining must also occur in light of the complexity and high-voltage components on board the vehicle (IEA, 2002, p.100). Furthermore, as Pilkington and Dyerson (2006) highlight, An equally significant problem for conventional car manufacturers is that their previously accumulated experience in designing and mass-producing automobiles, based on the internal combustion engine (ICE), may be ill-suited to the technologies required in producing Electric Vehicles (EV). Gärling and Thøgersen (2001) suggest that besides supportive national policies, skillful marketing is needed to get EV's accepted and diffused throughout society.

A straightforward improvement to the current generation of hybrids can allow them to be plugged into the electric grid and run in an all-electric mode for a limited range between recharging. This AFV is the plug-in hybrid, also called the e-hybrid. Also, plug-in hybrid electric vehicles (PHEV) use batteries and an engine just like a hybrid electric vehicle (HEV); only an expanded battery pack (> 30 km*)* and AC to DC converter allows off-peak grid electricity to be used to charge the battery pack. In a PHEV, the first 30–100 miles of travel each day would be without the engine running, indirectly using grid electricity (Suppes, 2006).

Since PHEV have a gasoline engine, and are thus a dual-fuel vehicle, e-hybrids avoid two of the biggest problems of pure electric vehicles. First they are not limited in range by the total amount of battery charge. If the initial battery charge runs low, the car can run purely on gasoline and on whatever charging is possible from the regenerative braking. Second, electric vehicles take many hours to charge, so that if for some reason owners were unable to allow the car to charge – either because they lacked the time between trips to charge or there was no local charging capability – then the pure electric car could not be driven. Thus, e-hybrids combine the best of both hybrids and pure electric vehicles (Romm, 2006). Environmentally, e-hybrids offer two potentially significant benefits. First, since they are designed to run all-electric for short trips such as commuting, they offer the possibility of being zero-emission vehicles (ZEVs) in cities. The best early uses of e-hybrids, according to Romm (2006), may well be to replace dirty diesel engine vehicles used regularly in cities, such as buses, maintenance vehicles, and delivery trucks. If we are unable to overcome the multiple technical and practical hurdles to hydrogen fuel cell cars, then e-hybrids may be the only viable option for urban zero emission vehicles.

According to Bradley and Frank (2007), the addition of electric vehicle energy management modes places additional requirements such as:

- meeting emissions control regulations during idle-less cold-start and on-off operation;
- advanced exhaust after-treatment for cold-start and on–off operation;
- meet noise and vibration constraints during on–off operation;
- show high efficiency over a wide torque and speed range;
- high duty cycle due to engine downsizing;
- meet evaporative emissions standards despite long engine off periods.

vi. Fuel Cells

Over the past decade, the fuel cell has risen in prominence as a future option for achieving sustainable transportation. In particular, polymer electrolyte membrane (PEM) fuel cells have the potential to be an excellent power source for transportation applications, and they have emerged as a replacement for the internal-combustion engine. Like batteries, fuel cells are efficient, quiet and have no moving parts. But they also have longer driving range, high power density, and (potentially) short refueling-time characteristics that make them more attractive as a substitute for internal-combustion engines. Fuel-cell systems can be powered by a variety of fuels including gasoline, methanol, ethanol, CNG, and electrolysis.

Vehicle emissions range from only heat and water if hydrogen is used as the fuel, to water plus CO_2 and small quantities of other regulated emissions if other fuels are used in combination with on-board hydrogen reforming. However, according to Romm (2006), it is unlikely that hydrogen vehicles would achieve significant (45%) market penetration by 2030.

Despite the environmental reasons for using fuel cells and the on-going development of fuel cell technologies, a number of hurdles could slow commercialization. IEA (2002, p. 114) names some of them as follows: development and testing, refueling infrastructure, onboard hydrogen storage, achieving scale economics, and codes and standards.

6.1.2 Emerging Technologies and Innovations

2nd Generation Biofuels

Many new technologies are emerging in the biofuel industry. These second-generation biofules use a wider range of feedstocks than 1st generation processes, including straw, wood or even waste paper. According to Dickie (2007), these biofuels are generally more efficient and environmentally friendly than first generation – but there is currently no technology available to produce them on a large-scale commercial basis, and there are a number of barriers which will have to be overcome before this can be achieved. It will require a huge amount of investment to establish an industry for 2nd generation biofuels, because the technology is far more complicated, and there is also the sheer bulk of the feedstocks to be considered.

Also, hydrogen and fuel cell technologies have a crucial role to play in meeting future energy needs in both rural and urban areas. Dincer (2006) argues that the development and utilization of such technologies should be given a high priority, especially in the light of increased awareness of the adverse environmental impacts and political consequences of fossil-based generation.

6.2 Patent Study

In the last decades, *patent analysis* has become increasingly popular among scientists studying R&D behavior of firms, industries and counties, to get more objective information on R&D activities. The use of patent information is gaining increasing attention in the fields of innovation and technology management. Patent data represent a valuable source of information that can be used to plot the evolution of technologies (Pilkington and Dyerson, 2006). Patent study illustrates how technological preferences have shifted over time (Van den Hoed, 2007).

6.2.1 Background

Carmakers have played an important role in putting new technologies on the map, both for the industry itself and for the regulatory context. Studies have shown how carmakers have been instrumental in getting new technologies adopted by the industry. Carmakers engage in R&D partnerships with promising entrepreneurs and use their technology in order to gain competitive advantage; also by gaining legitimacy and support from the regulatory context, thereby seeking rents by technological differentiation (Van den Hoed, 2007).

In a study by Van den Hoed (2005), the United States Patent and Trade Office (USPTO) database was used for analyzing automotive activities in alternative technology vehicles (ATV's; alternative to the ICE's), including battery electric vehicles (BEV's), hybrid electric vehicles (HEV's) and fuel cell vehicles (FCV's).

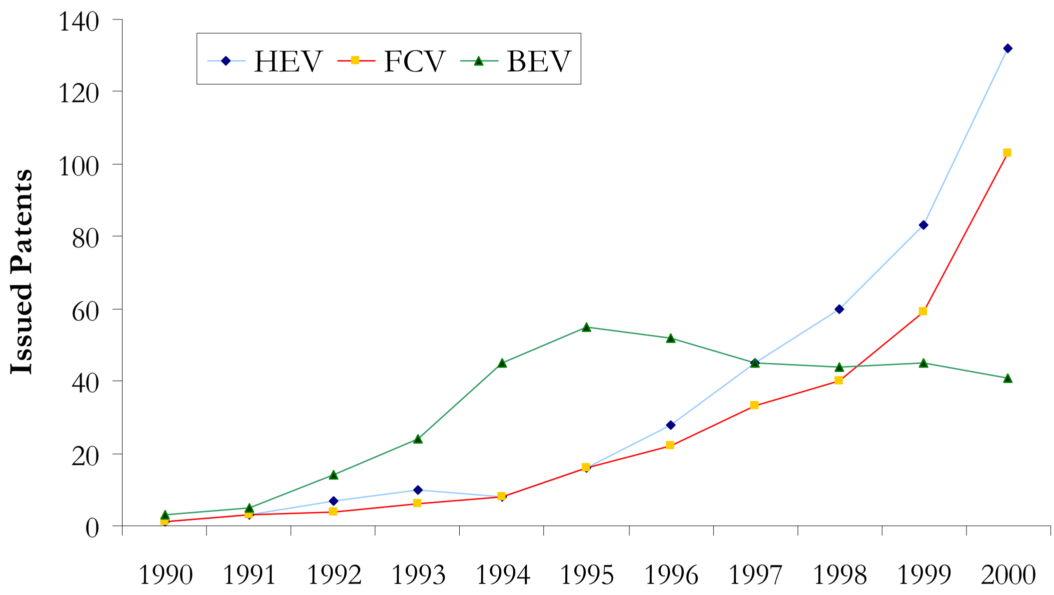


Figure 6-2 US Patents in Alternative Fuel Vehicles Applied For by Automotive Firms
Source: van den Hoed (2005)

Figure 6-2 shows that by 2000 close to 50% of all AFV related patents were HEV-related, 35% FCV-related, and 15% to BEV. A moving average of 2 years is used in order to level out annual fluctuations. This patent data regarding alternative technologies reveals that there has been a major tendency towards HEV's and FCV's in particular. Therefore, in the following section, a more comprehensive study of the issued patents of the aforementioned technologies will be carried out in Europe in the 1990 to 2007 period. The patent information is extracted from The European Patent Office database[4] (so-called "esp@ce Portal"[5]).

6.2.2 The Hybrid Electric Technology

This section entails a patent survey of the Hybrid Electric Technology (HET). In this study, an advanced search was done in the EP[6] section of the database. The query included the following keywords in the title:

"hybrid" AND "vehicle";

However, due to system limitations, it is not possible to search within date ranges. Therefore, the whole data needed to be classified manually. The search returned 457 entries. Thereafter, a relevance study of the patents was performed. For this purpose, all patent abstracts were studied thoroughly; and the issued patents were classified into:

A: "most likely relevant for hybrid vehicles"; and

B: "most likely not relevant for hybrid vehicles";

where 15 patents were classified as "B". A summary of the query and the results is provided in Table 2.

Table 6-2 Summary of the Hybrid Electric Technology Patent Study

Query Keywords	Total results	Results within 1990-2007	Relevance	
			A	B
"Hybrid" AND "Vehicle"	457	456	441	15

[4] www.epo.org

[5] www.espacenet.com

[6] European Patent

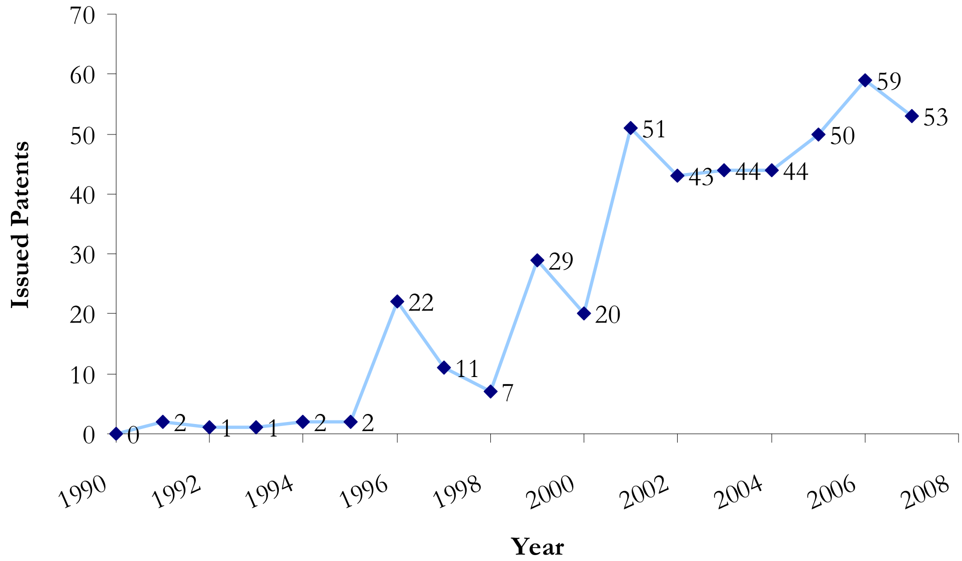


Figure 6-3 Frequency of issued patents in each year

As shown in Figure 6-3, in the 1991 to 1995 period, totally 8 patents were registered with an average of 1.6 patents per year. However, in the following 5 years, totally 89 patents were registered, where the average of issued patents per year (17.8) is approximately 11 times more in comparison with that of the antecedent period. This is not so surprising however, since this period corresponds to the "HET-boom" with the introduction and mass-production of Toyota Prius. In the following 7 years, totally 294 patents are issued which is almost 3 times more than the total issued patents in the previous decade. The trend shows that there is an-ever rising interest among manufacturers in this area.

Table 6-3 highlights the companies with highest number of registered patents within the HET which are relevant to the automotive industry. The frequency of their corresponding patents is depicted in Figure 6-4. The automotive industry involves a broad range of alliances and partnership which makes the classification task rather difficult. So, here, 18 patents held by direct partners of Toyota are shown in a distinctive color. Also Nissan and Renault are studied separately despite the fact that they hold some mutual patents between 2002 and 2004.

Table 6-3 Companies with highest number of registered patents in HET

Assignee	Toyota	Honda	Nissan	Ford	Bosch	Renault	VW	BMW
Issued Patents	86 (104)	82	60	16	14	13	8	7

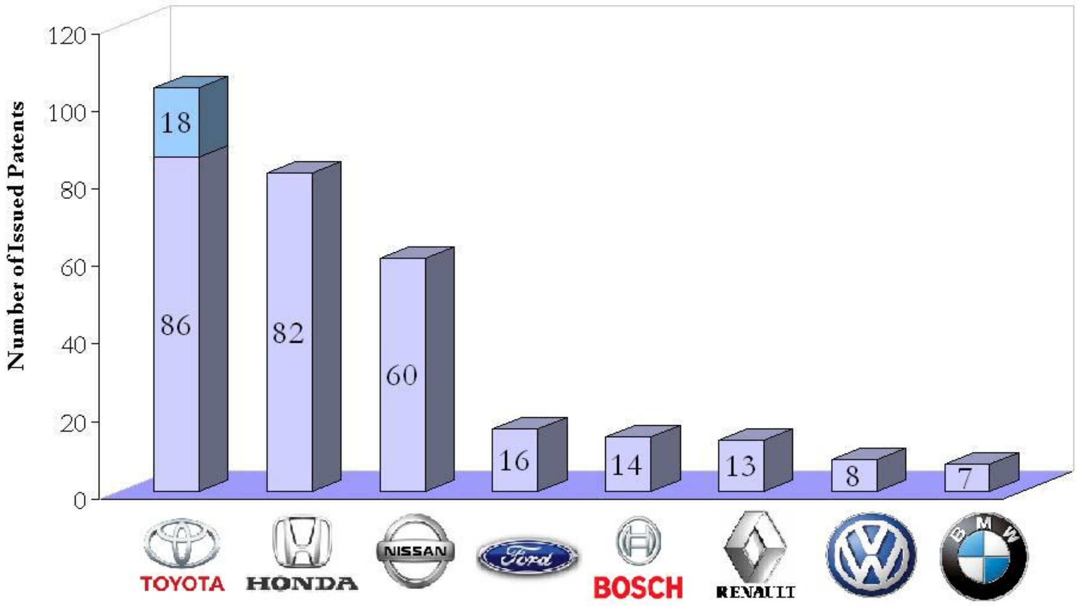


Figure 6-4 Frequency of registered patents in HET by leading companies

The data shows that the Japanese companies are the pioneers in registered patents in HET. Figure 4 obviously shows that approximately 57% of the issued patents are assigned to "Toyota", "Honda", and "Nissan". However, except for Ford – which holds about 4% of the issued patents – other American manufacturers or European automotive giants rarely have any issued patents or are laggards. There is a great concern why others seem to be quite passive.

A rather interesting issue that can be derived from Figure 4 is that although Bosch is not an automotive manufacturer, it is ranked among the leading companies having registered patents in HET; and despite being a major supplier to VW Group (including VW, Audi, and Škoda) and BMW, stands head and shoulders above them in this respect. This could have some managerial perspectives regarding which partner should be more focused on R&D and take the lead in registering patents, and which side should be the integrator and take coordinating role. This in turn is a major concern in shaping the power structure in the value chain.

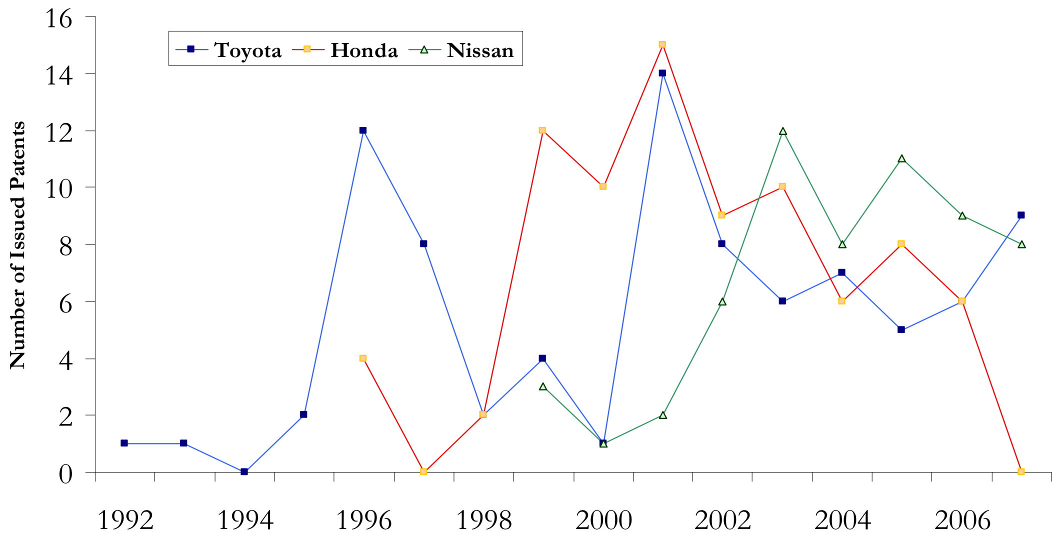


Figure 6-5 Issued patents by the leading companies

In Figure 6-5, the annual amount of issued patents by the leading companies (i.e., Toyota, Honda, and Nissan) is illustrated. As shown in Figure 5 Toyota was the earliest in registering patents in HET, and was the one and only till 1996 when Honda entered the business. This year Toyota reached a record-high level of patents which lasted for six years. This is not surprising since their Prius was introduced in 1997. The same case exists for Honda, the record-holder with 15 patents in 2001 – in the beginning of the millennium when they introduced their hybrid "Insight".

Finally, a thorough classification study of the issued patents was done within their corresponding International Patent Classifications (IPC's). The study shows that the relevant patents were within 18 major classes. A brief description of these classes and their respective frequencies are provided in Table 6-4. This shows that most of the patents were within "Physical or Chemical Processes or Apparatus In General", "Combustion Engines", and "Engineering Elements and Units General Measures for Producing and Maintaining Effective Functioning of Machines or Installations Thermal Insulation In General" classes. Then, 52 patents are classified as having electric applications which are basically in the "H" class.

Table 6-4 Frequency of the different patent classes

IPC	Description	Frequency
A61	Hygiene	1
B01	Physical Or Chemical Processes Or Apparatus In General	2
B29	Working Of Plastics Working Of Substances In A Plastic State In General	1
B60	Physical Or Chemical Processes Or Apparatus In General	1104
B62	Land Vehicles For Traveling Otherwise Than On Rails	14
B63	Ships Or Other Waterborne Vessels; Related Equipment	1
C22	Metallurgy; Ferrous Or Non-Ferrous Alloys; Treatment Of Alloys Or Non-Ferrous Metals	1
F01	Machines Or Engines In General	20
F02	Combustion Engines	59
F04	Positive Displacement Machines For Liquids; Pumps For Liquids Or Elastic Fluids	1
F16	Engineering Elements And Units General Measures For Producing And Maintaining Effective Functioning Of Machines Or Installations Thermal Insulation In General	44
F23	Combustion Apparatus; Combustion Processes	1
F28	Heat Exchange In General	2
G01	Measuring	6
G05	Controlling; Regulating	2
H01	Basic Electric Elements	20
H02	Generation; Conversion Or Distribution Of Electric Power	30
H05	Electric Techniques Not Otherwise Provided For	2

6.2.3 The Fuel-Cell Technology

This section entails a patent survey of the Fuel Cell Technology (FCT). In this study a similar search to that of the HET was done in the EP section of the database. The query included the following keywords in the title:

"fuel cell" AND "vehicle";

Table 6-5 Summary of the Fuel Cell Technology Patent Study

Query Keywords	Total results	Relevance	
		A	B
"Fuel Cell" AND "Vehicle"	58	57	1

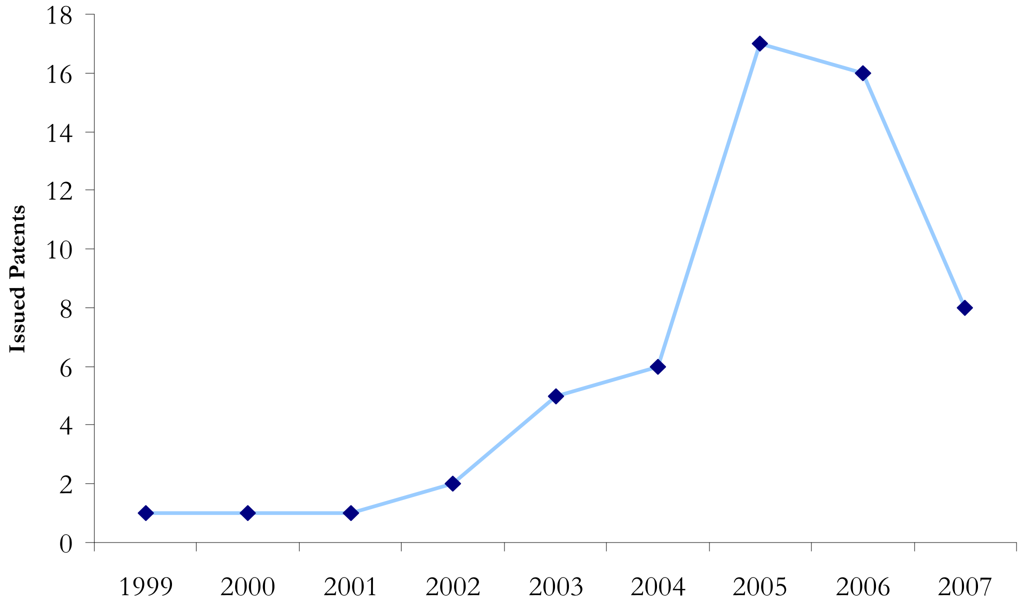


Figure 6-6 Frequency of issued patents in each year

Again, a relevance study of the patents was performed. For this purpose, all patent abstracts were studied thoroughly; and the issued patents were classified into "A" and "B" classes mentioned earlier where only 1 patent was classified as "B". A summary of the query and the results is provided in Table 6-5.

As shown in Figure 6-6, from 1999 only one patent was issued annually; however, after from 2002, the graph gets an increasing slope. This could be linked to the introduction of "Honda FCX" to the market. The graph reaches its climax in 2005 where more than the whole patents registered since 1999 were issued. The trend obviously shows that there is a rising interest among manufacturers in FCT. The declination in 2007 might be due to the fact that some of the issued patents might have been pending for publication in the database at the time of the study.

Table 6-6 shows the manufacturers holding the most number of registered patents within the FCT which are relevant to the automotive industry. The frequency of their corresponding patents is depicted in Figure 6-6. Again, here, Nissan and Renault are studied separately.

Table 6-6 Companies with highest number of registered patents in FCT

Assignee	Honda	Nissan	Renault	Toyota
Issued Patents	16	9	8	8

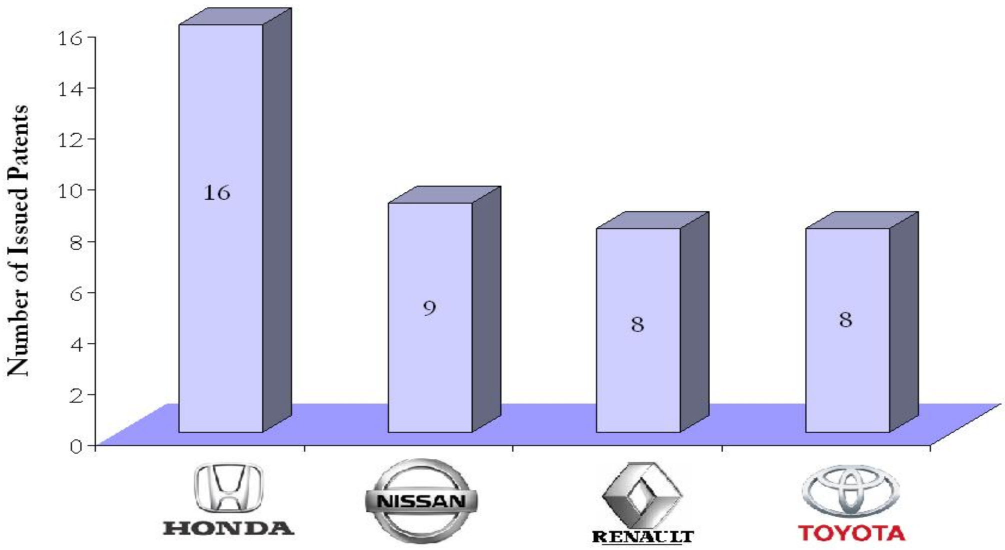


Figure 6-7 Frequency of registered patents in FC by leading companies

The data shows that the Japanese companies are the pioneers in registered patents in FCT. Figure 6-7 reveals that almost 58% of the issued patents are assigned to "Honda", "Nissan", and "Toyota". Also, Renault's rank, as the only European manufacturer among the leaders, might be due to their close alliance with Nissan. Moreover, this lead to a close partnership with Nuvera Fuel Cells, – a pioneer in FCT – since 2004. Again, as in the HET case, there is a concern why other automotive manufacturers have attained a passive strategy.

In Figure 6-8, the annual amount of issued patents by the leading companies is illustrated. Here, Honda was the earliest in registering patents in HET with its FCX. Since 2005 Honda's annual registered patents have doubled which could be linked to the introduction of their new "FCX Concept" and "Clarity".

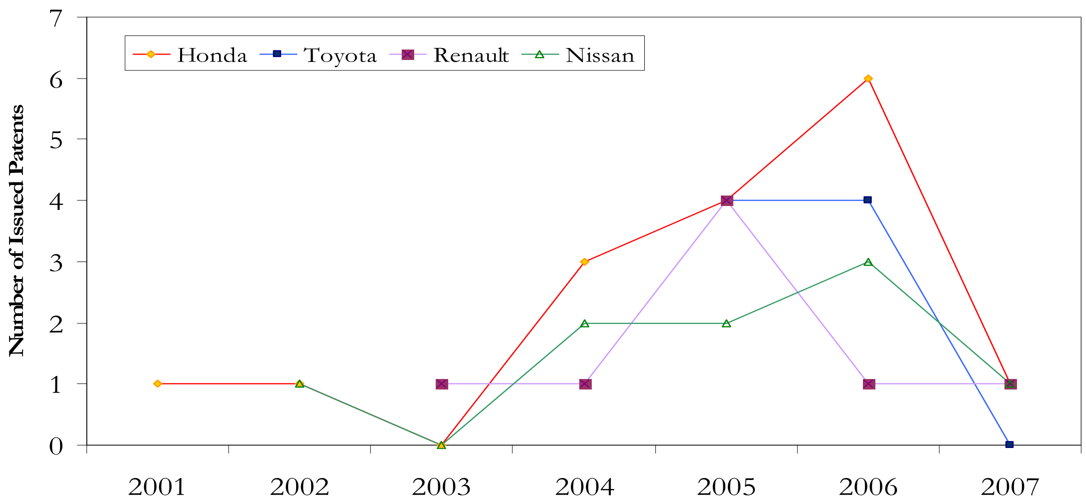


Figure 6-8 Issued patents by the leading companies in FCT

Table 6-7 Frequency of the different patent classes

IPC	Description	Frequency
B01	Physical Or Chemical Processes Or Apparatus In General	1
B60	Physical Or Chemical Processes Or Apparatus In General	86
B62	Land Vehicles For Traveling Otherwise Than On Rails	9
C01	Inorganic Chemistry	4
F17	Storing Of Distributing Gases Or Liquids	15
F23	Combustion Apparatus; Combustion Processes	2
H01	Basic Electric Elements	47

Finally, a thorough classification study of the issued patents was done. The study shows that the relevant patents were within 7 major classes. A brief description of these classes and their respective frequencies are provided in Table 6-7. This shows that most of the patents were within "Physical or Chemical Processes or Apparatus In General", and "Basic Electric Elements classes.

6.2.4 The Battery Electric Technology

In this section, a similar study to the previous sections was done regarding the Battery Electric Technology (BET). The query included the following keywords in the title:

"battery electric" AND "vehicle";

However, the search – and any other combination of the keywords – retrieved no results in the database. This in turn shows the lack of interest among the manufacturers to invest in BET-related R&D projects. This is rather surprising since the Norwegian "Think Public" has introduced the "Th!nk" models in Europe. However, searches within the database with "Think" in the "Applicant" or "Inventor" fields retrieved no relevant results.

6.3 Sales Data

In this section of the thesis, a brief overview of the sales data of the leading automotive companies noted in the in patent study – Toyota, Honda, and Nissan – will be provided. This information will be later used in Chapter 7 for further analysis.

6.3.1 Toyota

Toyota Motor Corporation is a leading automobile manufacturer in the world.

Brand and Product Portfolio

Toyota Corporation, apart from Toyota, owns some other brands; including Lexus, Hino, Scion, and owns a large majority of shares in Daihatsu. Also, a minority of shares in Fuji Heavy Industries, Isuzu Motors, and Yamaha Motors are held by Toyota. It covers the luxury sector by its "Lexus".

Toyota produces a wide range of light passenger vehicles, mini-vans, SUVs, and trucks.

Its broad portfolio of HEV's includes Prius, Estima Hybrid, Alphard Hybrid, Harrier Hybrid, Kluger Hybrid, Camry Hybrid, and some others.

Corporate Values and Culture

Toyota's corporate values are to be a good corporate citizen who is constantly winning the trust and respect of the international community (Toyota Official Website[7]). Toyota aims at having a long-term growth while striving for harmony with the community, society, and the environment. Its main focuses are in the key areas of environment, safety, and energy. Toyota strives to pursue a sustainable manufacturing system. Quality is a primary goal and the customers always come first.

Market Position

Toyota has production facilities in 26 countries and dealerships in more than 170 countries. It took over GM by selling over 2348 million cars worldwide in the first quarter of 2007. The fiscal 2007 was a record-year for Toyota when net revenues, operating income, and net income raised 13.8%, 19.2%, and 19.8% respectively.

The Prius was first introduced in Japan in 1997, with a redesign of the batteries by the year 2000. In 2004, the second-generation entered the market. Prius was designed to reduce emissions during urban driving.

[7] http://www.toyota.com/about/our_commitment/index.html (last accessed 26 April 2008)

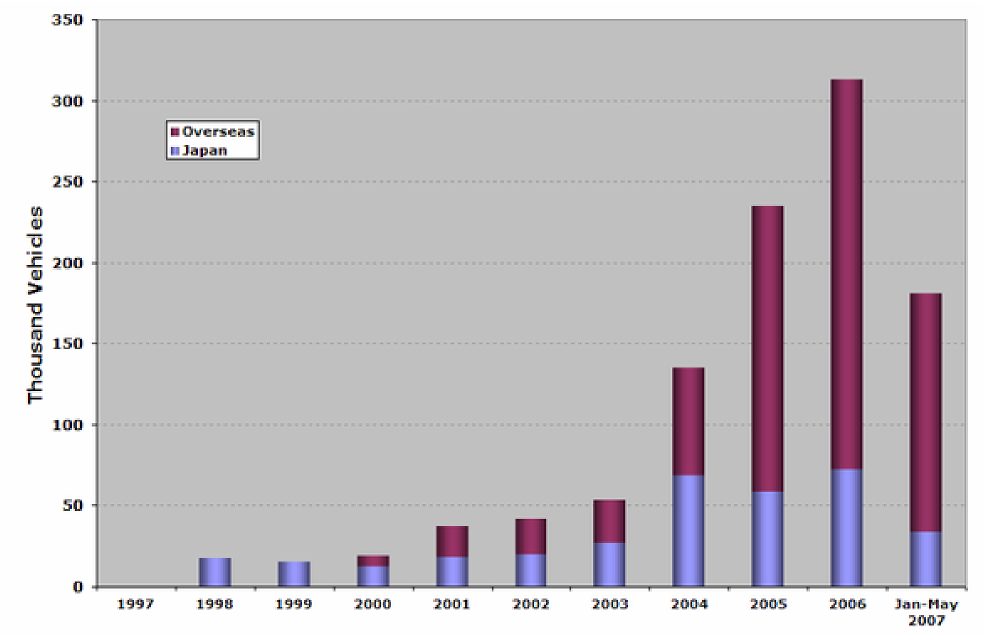


Figure 6-9 Toyota's Global Annual Hybrid Sales
Source: Geerncarcongress.com[8]

In 2006 Toyota was the worldwide market leader in HET with having 91% of all hybrid vehicles in Europe and 76% in the US. It is also planning to introduce hybrid in all product range by 2012. Figure 6-9 shows the total sales of HEV by Toyota.

Technologies

The greatest benefit Toyota has in its production system is the TPS (Toyota Production System) which is a major concept in "lean manufacturing".

The following technologies are among the various sustainable innovations in the engine systems developed or applied by Toyota:

- D-CAT (Diesel Clean Advanced Technology) with DPNR (Diesel PM and NO_X Reduction system);
- Synthetic Gas-To-Liquid (GTL); and,
- Fischer-Tropsch (FT) synthetic diesel.

Also, they launched the first-ever Flex Fuel Vehicle (FFV) which runs on gasoline, ethanol, or any combination of the two in Brazil. Moreover, by cooperating with Isuzu, Toyota expects to start Diesel Hybrid Vehicle production by 2010. Furthermore, Toyota is running a project – led by Panasonic EV Energy – to develop a practical lithium-ion battery to power hybrid engines.

6.3.2 Honda

Honda Motor Co. is one of the largest automobile companies in the world established in 1946.

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[8] http://www.greencarcongress.com/2007/06/global_cumulati.html (last accessed 30 April 2008)

Brand and Product Portfolio

In addition to "Honda", Honda Motor Co.'s line of luxury automobiles is branded as "Acura".

It produces automobiles, motorcycles, trucks, robots, jets, water crafts, and several other mobile products.

Corporate Values and Culture

Honda's strategy has consistently emphasized "innovation", "independence", and "environmental friendliness".

Its CSR and environmental vision stretches through the value chain. According to Honda Official Website

"It is important for us to improve the environmental performance of our products to enable our customers to use the products without being concerned about the impacts caused by these products to the global environment. In their lifecycles, our products tend to cause the largest environmental impacts while they are in use, and we need to reduce such impacts. To meet this requirement, Honda is striving to build a better relationship between people, the earth, and our products by setting severe voluntary standards for environmental conservation, including cleaner exhaust gases and higher fuel efficiency"[9].

Market Position

Honda was the first automotive company to market HEV's in the US by releasing "Insight" in 1999. According to Davis *et al.* (2008), Honda's hybrid models are designed for fuel-efficiency, in contrast to Toyota's HEV's that are designed for reduced emissions. By the end of 2006, Toyota's hybrids were outselling Honda's by almost four-to-one which led Honda to cease the production of "Insight".

For the year ended April 2006, Honda boasted operating profits of $5.1 billion. However, according to Welch (2003), it was estimated that Honda lost as much as $8000 per car when the hybrids were originally launched due to insufficient volume to achieve economies-of-scale.

It resisted the overwhelming range of mergers and acquisitions in the late 1990s and maintained its independence.

Technologies

The "Insight" HEV was designed as a "parallel" hybrid system, where the electrical system and the gasoline power system run in parallel to concurrently turn the transmission, which in turn rotate wheels.

[9] http://world.honda.com/environment/ecology/conservation-activities/product-development/index.html (last accessed 1 May 2008)

Davis *et al.* (2008) contend that although the electric car was not a commercial success, developing the electric vehicle built a foundation of expertise that Honda would employ in its development of FCT. Honda developed FCV's by introducing the award-winning "FCX" in 2002 which became the world's first fuel-cell to be sold to customers.

Moreover, next-generation diesel engines were brought into consideration by Honda with plans to introduce new vehicles with clean diesel technology by 2009. Also, they released "Civic GX" natural gas vehicle in 2005.

In line with most of the Japanese production companies, Honda applies Just-In-Time (JIT) inventory ordering and storage, as well as lean manufacturing processes.

6.3.3 Nissan

Nissan Motors is a leading Japanese car manufacturer established in 1932.

Brand and Product Portfolio

Besides "Nissan", "Infiniti" serves as Nissan Motors' luxury brand.

It produces an extensive range of cars and trucks.

Corporate Values and Culture

Nissan's vision could be summarized as "Bringing a rich and enjoyable car lifestyle to all"[10] where customers are provided with an enjoyable driving experience and a richer automotive lifestyle, and life and society are enhanced (Nissan Official Website). It follows a clear CSR vision (Figure 6-10).

Nissan's main values are to "optimize product development" and to "deliver highly innovative technology". Infiniti's main values are to focus on "advanced design and powerful performance" and on "highly refined style and responsiveness".

Figure 6-10 Nissan's Approach to CSR
Source: Nissan Official Website[11]

[10] http://www.nissan-global.com/EN/OURBRANDS/ (last accessed 28 April 2008)
[11] http://www.nissan-global.com/EN/COMPANY/CSR/ (last accessed 28 April 2008)

Nissan introduced "The Green Program 2010" in 2006 which focuses on products, technologies, and manufacturing activities as a main environmental strategy. It is planned to achieve the company's environmental philosophy, which consists of the symbiosis of people, vehicles, and nature.

Market Position

Nissan produced more than 3,200,000 cars in 2006 which made the company take the seventh position on the global market.

Nissan rolled out its "Tino Hybrid" in 2000 and "Altima Hybrid" in 2007. It also presented "PIVO" in 2005 which is a next-generation BEV empowered by a compact lithium-ion battery and Nissan's "Super Motor".

Technologies

Nissan basically has worked on five main technological capabilities in terms of motive power for light cars; namely, HET, Gasoline Diesel, Biofuel, BET, and FCT.

Nissan introduced the following technologies for ICE:

- HC-NO_X Trap Catalyst;
- Variable Valve Event and Lift System (VVEL); and,
- Super Motor.

Also, the introduced innovations in FCT by Nissan are:

- In-House Fuel Cell Stack;
- 70 MPA high-pressure hydrogen storage system;
- Laminated-type Lithium-Ion Battery for EV; and,
- Compact Inverter.

Nissan signed an alliance with Renault in 1999 through which linked by cross-shareholdings, they hold coherent strategies, common goals and principles, result-driven synergies, and shared best-practices.

6.4 Summary

In this chapter, first the major innovations in the automotive power-trains were overviewed; and, thereafter, a patent study of the three main technologies in this field – HET, FCT, and, BET – was carried out in Europe through which the pioneers in holding patents were determined. Following the patent study, a brief sales study of these companies was done which will be the basis of the next section dealing with Discussion.

Section III

DISCUSSION

7. Analysis

This chapter deals with the analysis of the thesis based on the theoretical framework and the empirical study chapters. First, a brief analysis of the patent and sales study is provided, and then, the research questions are discussed.

7.1 Patent and Sales Study Results

The significance of patent analysis and its contributions to innovation management was highlighted in part 5.6. In the patent study of HET, BET, and FCT in Europe, run in part 6.2, it was revealed that these technologies are gaining ever-increasing attention by automotive manufacturers.

Figure 7-1 shows the amount of issued patents since 1990 for these technologies. In comparison with the study on the AFT patents in the US by Van den Hoed (2007) depicted in Figure 6-2, it seems obvious that both in HET and FCT, follow a similar increasing pattern of the amount of patents. Moreover, since 1996 the amount of patents in BET in the US has undergone a decline whilst the other two technologies have been brought into focus. This signifies a lack of interest among automakers to pursue R&D and allocate innovation budgets in BET. This is in line with the European results wherein since the mid-90's the amount of patents in HET experiences a huge increase.

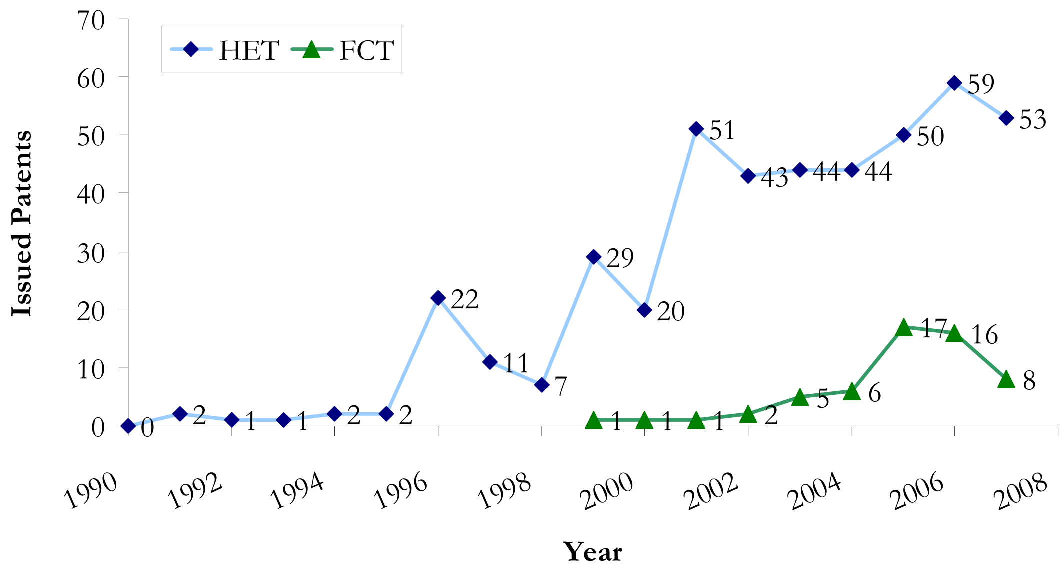

Figure 7-1 European Patents in AFV's Applied For by Automotive Firms

However, in Europe the first patent in FCT was issued in 1999. The interesting point to note here is that the applicant of this first patent in FCT was "DBB Fuel Cell Engines GmbH". This company, based in Nabern in Germany, is a result of an alliance formed between DaimlerChrysler and Ford Motor Company and cooperates with Ballard Power Systems for the development and manufacturing of fuel cell engines. Also, the only patent in 2000 was assigned to XcellsiS GmbH which is also a majority-owned subsidiary of DaimlerChrysler AG while the next patent assigned to DaimlerChrysler AG is registered in 2005. This could be a typical example of the initial shakeouts in this technology.

Moreover, despite the fact that the Norwegian "Think Public" has introduced the "Th!nk" as a BEV, the search in the database retrieved no results. This obviously shows that BET has not been taken into account as a dominant technology in the near future.

The patent study revealed that the Japanese carmakers are head and shoulders above others in AVT; where both in HET and FCT, Toyota, Honda, and Nissan hold the first ranks. The only European automotive manufacturer that has an appealing number of patents in FCT is Renault which in turn has close partnership with Nissan. Other giant manufacturers, including the American carmakers, seem to be quite passive. Only Ford holds 16 patents in HET since 2002 when its first patent was assigned. The reason why Ford has adopted a "follower" approach might be linked to the high level of uncertainty or lack of technological knowledge.

Some other companies that are absent in the ranking have acquired the knowledge through partnerships or licensing. A conspicuous instance in HET could be Bosch which is not an automotive manufacturer but is a major supplier to several carmakers including VW and BMW. As discussed in part 6.2.2, this is a critical concern in shaping the power structure in the value chain. The rest of the manufacturers seem to have applied a "hands-off" approach and tend to focus on their own market niches.

Another notable, and yet logical, issue with regards to patents is that in the chronological study of the issued patents (see Figures 6-5 and 6-6), by the introduction of a market-shaking product, the amount of patents reaches a peak or increases drastically. Instances could be the roll-out of Toyota Prius and Honda Insight HEV's in 1997 and Honda FCX FCV in 2002.

Finally, the classification study of the patents revealed that most of the patents in HET and FCT were classified as "Physical or Chemical Processes or Apparatus".

According to GreenCarSite[1], in the first six months of 2007, over 23,000 environmentally friendly cars were sold in European, which shows a rise of

[1]http://www.greencarsite.co.uk/GREENNEWS/hybrid-car-market.htm (last accessed 1 May 2008)

25% over the same period last year. The growth indicates that low-emission automobiles made up for around 15% of all new registered cars.

It also highlights the significance of governmental regulations and support of sustainable products by studying the case of Sweden.

The report shows that Europe had a share of around 7.68% in global hybrid sales in 2005. In 2006 Toyota had over 90% of the European market share.

Obviously, Toyota is in the driving seat in HET. It introduced Prius to the Japanese market in 1997 and then to an initial niche market in the US in 2000 thanks to its CSR reputation. As mentioned in part 6.3.1, recently, Toyota offers HET in several vehicles to cover various market segments.

The same story applies to Honda as the leader in FCT by its FCX, and yet more recently, Clarity. It was the first carmaker to release a HEV (Insight) to the US market – which was bond to cease the production before 2007 – and is offering HET in several products now.

Toyota and Honda took a leader/offensive approach when it came to HEV's (see part 3.7) and basically are benefiting the risk they took (see Table 2-2). This, in turn, provided Toyota with a "first-mover advantage" as discussed in Table 2-2, while others tended to wait for the market to become mature to lessen the level of uncertainties.

The other pioneer in this respect is Nissan which also has a portfolio of sustainable vehicles. Currently, it produces Tino and Altima HEV's and it introduced the BEV PIVO in 2005.

From the corporate value perspective discussed in part 6.3, apparently, these companies have come to a true belief of the corporate responsibilities (see part 2.2.2) through their value chains (see part 2.1.4). Beyond these Strategic CSR's, their Ethical and Altruistic CSR's have paved the way for having a "Green" image (see parts 2.1.3, 2.2.4) which has had a significant effect on the level of competitive advantage (see part 2.2.3) which could have direct and specific business benefits, strengthen the legitimacy of the business community, boost innovation and flexibility levels, and enhance trust. Allegedly, as discussed in the Technology Acceptance Model in part 3.6, the higher the level of trust and perceived usefulness of such sustainable products, the higher the level of innovation adoption by the customers. Form a brand management perspective such an advantage would be intangible and difficult to duplicate (see part 2.2.4). This is in line with the implications of the concept of cause-related marketing (CRM) or third wave branding discussed earlier. Above all, the level of CSR would affect different stakeholders (including employees, customers, invertors, suppliers, the community, and the environmental groups).

Moreover, the discussion provided in part 2.1.4 implies that from a strategic management point of view, the level of sustainability directly affects the dimensions of the strategic planning and operational (see 2.2.3) effectiveness.

With regards to the linkage between the level of organizational changes and ambition in sustainable management, it seems that second- and third-order changes would be more effective in the long-run with gradual modification of existing organizational structures, systems, objectives and values in order to adopt a sustainable way of thinking in the companies.

As discussed earlier, in addition to incremental process innovations in the automotive industry, innovations in the engines – as typical products – have been radical or disruptive in several cases to cope with increasing regulation demands (technological or complex). However, due to the fact that product innovations are exposed to rapidly changing technologies and competition, it seems that architectural innovations in the existing technologies in the power-train – specially HET – is the least risky approach that would also result in a higher level of acceptance by the market (see Magnusson *et al.*, 2003). However, some other authors contend that HET is a typical incremental innovation (see Van den Hoed, 2007). The implications are different to a great extent with regards to the KM concerns. In case of architectural innovation there is a need to devote extensive resources to defining new interfaces between different fields of knowledge (i.e. to knowledge integration) and this may have huge implications for organization and strategy. For instance, Toyota has acquired Panasonic EV as its battery supplier and together they have developed into a major manufacturer of electric motors. However, in an incremental innovation case, there might be an extensive reliance on established organizational routines and structures. This could be contrasted with the European contenders, whether their in-activity could open up for suppliers (e.g., Bosch) to integrate forward and take the role as a "hybrid power-train integrator" or not.

Above all, it appears that, in a typical technological discontinuity case, the automotive industry is experiencing a fluid phase characterized by extensive experiments and failures (see part 3.5) where the incumbents are generally following competence-enhancing technological capabilities.

In this regard, applying KM tools drastically influences sustainable vehicle innovation capabilities (see 4.3, 4.4). As discussed in part 4.2.1, for such a complex product development, higher levels of modularity of knowledge will enhance competences through decomposing knowledge into specific routines within the company (see part 4.4.2). Moreover, organizational learning processes play a major role in this respect (see 4.5). However, from a global competition view, tacit or know-how knowledge is the key to product innovation (see 4.2.1); Hence, the importance of patent – as a technological knowledge – could be highlighted again in gaining sustainable competitive advantage.

7.2 How Research Questions Were Addressed

This part summarizes how the research questions stated in part 1.3 were covered in the thesis.

- What are the main challenges and drivers of the automotive industry in sustainable vehicle development?

The main challenges the automobile industry is facing arise from the ever-rising concerns regarding the environment. In this regard, the concept of sustainability, as discussed earlier, is the main driver of the whole movement towards sustainable vehicle development. Hence, the significant issues of sustainable management and CSR were covered in a separate chapter (see Chapter 2); wherein, the strategic innovation management perspectives were studied.

Thus, the automotive industry is left with no chance but to produce sustainable vehicles. However, this requires a long-term commitment to R&D in yet immature technologies with an uncertain market. These challenges were discussed basically throughout several chapters of the thesis.

The major technologies on sustainable vehicle development were discussed in part 6.1 on "Innovation in the Automotive Industry". The study shows that the main focus in sustainable vehicle development is on the power-train. The recent and emerging technologies being applied in this field were overviewed in part 6.1.2, and among them, HET, BET, and FCT have been commercialized and seem to be prevalent in the upcoming future. Therefore, the empirical study of this thesis was concentrated on these three aforementioned technologies.

- How does technological knowledge (specifically patent) analysis contribute to innovation management?

Knowledge has long been regarded as the cornerstone in innovation management. So, Knowledge Management policies drastically affect innovation and NPD (see part 4.4). This topic was addressed in Chapter 4. Among various types of knowledge, patent – as a technical knowledge – was applied in the empirical study of the thesis. Patent information could be used to illustrate the chronological shift of technologies and is applied hugely in innovation and technology management. How patent analysis helps companies manage innovation was discussed in parts 5.6 and 6.2 of the thesis. The study shows that patent study is a valuable source to analyze which technologies have been in focus and how they have evolved over time.

- Which automotive companies are pioneers in sustainable vehicles and have been more active in patent registration in Europe?

The empirical study in part 6.2 reveals that the Japanese carmakers hold the most number of patents in sustainable vehicles. The patent analysis shows that Toyota, Honda, and Nissan are the leaders in HEV's. The same rule applies to FCT where these companies along with Renault are the most active ones in patent registration. In order to distinguish the pioneers in sustainable vehicle production, a sales study was carried out in part 6.3. No wonder that the carmakers holding the most number of patents in this field were the leaders in production. The study shows that Toyota owns around 90% of the European market share.

More over, marketing perspectives were issued throughout the thesis in most of the chapters. For instance, in parts 2.1.3 on Going "Green"; 2.2.4 on Corporate Social Responsibility and Marketing Management; 3.3.3 on Market Innovation; 3.6 on Innovation Adoption: The Technology Acceptance Model; and 4.7 on Knowledge Management and Marketing, the marketing track of the thesis could be followed. Also, in the empirical study and the analysis, the sales data are used for the selected automotive companies.

7.3 Summary

Chapter 7 covered the analysis of the empirical study of the thesis based on the theoretical framework; wherein the patent and sales study results were discussed. In the second part of the chapter, the research questions proposed in part 1.3 of the Introduction chapter were re-addressed and the respective studies and their level of coverage were reflected. This chapter paves the way for the conclusion provided in the following chapter.

However, it seems necessary to emphasize that as it is a long-term vision there is a need to take strong action in the short and medium term in order to address current environment and energy concern.

8. Conclusion

Within this chapter the thesis will be concluded. First, a summary of the empirical study and analysis will be provided. Later, areas for future research will be proposed.

8.1 Summary

This thesis dealt with the concept of innovations in the automotive industry. The study was divided into two main sections; namely, theoretical framework and empirical study. In order to pinpoint the main drivers of sustainable vehicle development, CSR and sustainable management were discussed in Chapter 2. Later on, the literature on innovation management was reviewed; where, different innovations types, levels, and phases were covered. Moreover, in this chapter, the Technology Acceptance Model was overviewed. Within Chapter 4, the significance of Knowledge Management in innovation was discussed; since in the empirical study, patent – as technical knowledge – was applied.

Chapters 5 and 6 constructed the empirical research. First, the research methods used in the thesis were discussed and then, in Chapter 6, the empirical study was carried out. In this chapter, initially, the major technological innovations in the automotive industry were reviewed, then, the patent study of HET and FCT revealed that these technologies are gaining increasing attention by manufacturers and seem to be prevalent in the forthcoming future. However, the products in this field are experiencing a diverse range of trial and errors and are yet to seek for a dominant design. Surprisingly, European carmakers were missing among the active companies in sustainable products and the Japanese Toyota, Honda, and Nissan were the pioneers in holding patents, and respectively, had the largest market shares. Moreover, since these companies started commercializing their "green" products to a strategic niche market in the beginning and then expanded their target markets, it could be concluded that strategic niches may foster innovations (either radical or incremental). Also, the studies showed that these companies have a clear CSR strategy and mission and are highly investing in R&D projects. Others tend to work on ICE development through incremental innovations. This shows that incumbent carmakers are seeking a balance between incremental and radical innovations when it comes to the engine. Besides improved ICE's, HET seem to dominate the market in the near future since it is gaining increasing adoption and acceptance and is passing its infancy. However, in the long-term, BEV's and some other next-generation AFV's might be on R&D agenda. Finally, the study showed that governmental regulations can foster innovations in sustainable vehicles and also sustainable vehicle development can foster environmental regulations as well.

8.2 Implications for Future Research

This thesis dealt with innovation management in the automotive industry as a specific case, and the focus was on patent analysis in the European market. An area of future research could be a comprehensive cross-case analysis of the European patent database with its American counterpart; since some companies tend to hold parents in their market. Another important area of research could be studying the transactions and partnerships in the automotive industry and how these alliances affect innovation policies.

Another field of study could be measuring the level of customer acceptance of environmental vehicles. This study could reveal customer attitudes towards such sustainable products and could be a hint for strategic and marketing management. A further relevant study could focus on how sustainable vehicles could boost the reputation and "green" image of a typical carmaker which could in turn be a value-added asset.

Other studies could address innovations in other vehicles components – than the power-train – which have environmental impacts. Also, this thesis was focused on the automotive industry with relatively complex products. Further researches could cover sustainable innovations in other industry sectors.

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