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RESPONSIBLE INNOVATION AT THE FIRM-LEVEL

TRACING IN CAR INDUSTRY

Tesis Doctoral presentada para obtener el título de Doctor por la

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Presentada por

Abel Zahínos Ruiz

Noviembre 2015

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Abstract

Innovation is an essential activity for the competitiveness and long-term success of firms. It has also contributed positively to increasing the living standards of millions of people during the last century. However, it is widely recognized that innovation co-produces unintended impacts on socio-economic and ecological systems. Existing mechanisms of control and authorization, i.e. regulations, are inefficient in preventing the diffusion of innovations which give rise to ethical, social, economic and/or environmental concerns. The inefficiency of regulations and the increasing capability of science and technology to create long-lasting and far-reaching impacts have stressed the need of introducing responsibility issues through innovation processes. The aim is to foster the generation of ethically acceptable, socially desirable and sustainable innovation. But, how can firms generate innovation in a more responsible manner?

The purpose of this thesis is to contribute to the development of a more responsible approach of innovation. In particular, the aim of the research is to propose and validate a framework for helping firms to innovate more responsibly. For achieving this aim, this thesis is organized around a two-stage research procedure. First, an extensive literature research is conducted to generate a theoretical framework explaining how to innovate more responsibly at firm-level. The literature research involves the review of definitions of innovation as well as of models and approaches explaining the process of innovation. Based on this research, it is proposed a new definition of responsible innovation which may be useful for guiding firms in their efforts to innovate more responsibly. On the other hand, the literature review reveals the shortcomings of existing theories and approaches of innovation for helping firms to innovate responsibly. Therefore, the emerging approach of Responsible Innovation (RI) is explored. This shows that three general frameworks for RI have been proposed so far. The analysis of these frameworks leads to the adoption of one as the most suitable candidate for addressing the research objective of this dissertation. The adopted theoretical framework suggests that the generation of RI is contingent on ensuring care of certain values for social, economic and environmental sustainability through the innovation process. For ensuring care of values, the framework proposes five dimensions: the Anticipation, Participation, Deliberation, Reflexivity and Responsiveness dimensions. As an evolving theory, the adopted framework shows two main shortcomings that requires further research: 1) the framework does not suggest methods that firms can use for deploying the dimensions through the innovation process; and 2) it presents little empirical evidence supporting its validity to promote RI. To overcome the first shortcoming, the five dimensions are further developed and a set of methods are proposed based on a literature review.

The second stage of this thesis focuses on the empirical research part. This part aims to overcome the second shortcoming of the adopted theoretical framework for RI, i.e. the little empirical evidence supporting its validity. Thereby, a multi-case study research strategy is adopted as the most suitable to test the validity of the mechanisms for RI identified through literature research. The research design involves the elaboration of a set of propositions based on the theoretical framework for RI. Then, three cases from the car industry are selected and analysed as potential instances of responsible innovation. The first case refers to an innovation process aimed to commercialize electric vehicles in Spain through new mobility services. The second case is an innovation process aimed at selecting and developing new Advanced Driver Assistance Systems for enhancing both the safety and competitiveness of certain vehicles. The last case is an innovation process that created a new safety system, called Multi-Brake Collision system, aimed at reducing the potential consequences of car accidents. The cross-analysis of the cases provides evidence which confirms the seven propositions and therefore the validity of the adopted framework for explaining how to generate RI. Conclusions and practical implications for firms attempting to innovate responsibly are drawn based on the case results.

The main contribution of this thesis is a set of validated mechanisms which can be used at the firm level for fostering the generation of innovation outcomes which contribute to social, economic and environmental sustainability.

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1 Introduction

1.1 The two sides of innovation

Since prehistorian times, humans have been characterised by the ability as species to imagine and create new artefacts and technologies and to use them to enhance our capabilities. The domestication of plants and animals, writing, the invention of money and the alphabet are only a few examples of *innovations* that we created and adopted over 3 000 years ago (Watson 2006). These have enabled us to create more and powerful technologies that we have used to transform the environment, improve our ways of living and expand our capabilities to the point that we have become a moulding force of the planet on which we live.

Nowadays, innovation plays a fundamental role and is an integral part of the structure of nearly all modern societies. Its relevance relies in its capability to generate value, both for customers who buy and adopt innovation, as well as for the companies that commercialize innovation outcomes (Tidd and Bessant 2009). Moreover, innovation is considered an essential activity to ensure economic growth and the creation of jobs, increase the living standards of people, as well as respond to environmental and demographic challenges. All in all, innovation is a strategic activity for both firms and policy-makers (Baregheh, Rowley et al. 2009)

In modern times, our scientific and technological capabilities are more powerful than ever. These have opened new avenues for the creation of innovations which satisfy societal needs in new and more efficient manners. Thus, innovations such as certain drugs, communication devices, computers and electronic systems, fertilizers, internal-combustion engine vehicles and a long, long etcetera, have contributed significantly to economic growth and increasing living standards of millions of people in the last century. Moreover, in the last decades, new technologies have emerged, such as nanotechnologies, biotechnologies, new information and communication and artificial intelligence technologies, to mention a few, which bring the promise of higher productivity and new waves of economic growth.

However, as our scientific and technological power increases, so it does our capability to create new risks and produce negative and global impacts through innovation. In literature, it is possible to find numerous examples of innovations whose impacts affected negatively human health, socio-economic and/or environmental systems (EEA 2001; Muniesa and Lenglet 2013). Some authors consider these innovations as irresponsible innovations (von Schomberg 2013). Exemplary cases are asbestos and chlorofluorocarbons, responsible for important health and environmental impacts (Witt 1996; EEA 2001). Irresponsible innovations were also certain financial products and services, such as Collateralized

Debt Obligations (CDOs) and Credit Default Swaps (CDS) (Muniesa and Lenglet 2013), whose careless use is the origin of the financial and economic crisis that hit the World since 2008. The electricity smart meters and the electronic patient record system projects in the Netherlands are other examples of irresponsible innovations. Those innovations were socially contested and finally not implemented, with the subsequent waste of relevant amounts of money, because they were unable to warrant the value of privacy (van den Hoven 2013).

Innovation is a future-creating activity, an activity that brings something new into the world and changes it (Grinbaum and Groves 2013). Under this view, irresponsible innovations can be considered as those innovations which bring a future that society (or a part of society) does not want, which create a future in which the values that societal actors have enshrined are compromised, in which those things society care about, are or could be threatened. von Schomberg (2013) suggests a categorization of irresponsible innovation in which he distinguishes 4 groups: i) innovations which are the result of technology push strategies (e.g. genetically-modified organisms as commercialized by Monsanto); ii) innovations which neglect fundamental ethical principles (e.g. the smart meter project in the Netherlands); iii) innovations derived from policy pull (e.g. the body scanners that the European Commission planned to introduce in airports as a security measure) and iv) innovations which are launched without taking into account their potential negative effects upon socio-economic and ecological systems (e.g. asbestos). All these types of innovations have something in common: innovations encompass (potential) consequences upon socio-economic and/or ecological systems which are against the values of those who are affected and/or concerned with innovation.

1.2 The research problem

The emergence of new technologies, such as nanotechnologies, synthetic biology and new information and communication technologies, have stressed the need to investigate how responsibility issues can be considered through the innovation process to enhance the safe embedding of innovation outcomes in society (Owen, Macnaghten et al. 2012). This need emerges due to several challenges posed by the characteristics and nature of modern innovations. On the one hand, there is an increasing awareness of the profound, global and long-lasting impacts of contemporary innovations. So, there is a need to find ways of conducting innovation so that its wider consequences are considered before they are materialized in order to avoid undesirable impacts.

On the other hand, scholars and policy-makers have come to the conclusion that existing mechanisms of control and authorization of innovation, i.e. regulations, are inefficient to ensure responsible behaviours and innovation outcomes. The inefficacy of regulations relies in several facts. First, it can take (many) decades among the diffusion of innovation, the understanding of their wider consequences, and the

appearance of regulations to control innovation and its effects. Hence, by the time that regulations may be issued, innovations may have been 'locked-in' in socio-technical systems and their consequences may have produced serious or irreparable damages. Moreover, 'lock-in' and path dependence phenomena may limit the capabilities or willingness of society to modulate or substitute innovation for more benign alternative, even though innovation produces significant negative impacts (Owen, Macnaghten et al. 2012; Owen, Stilgoe et al. 2013). Second, innovation is typically the result of the efforts of a network of actors working together within a set of social relationships (Grinbaum and Groves 2013). In this context, regulations may not be helpful to stimulate a responsible behaviour since it is usually difficult to identify the actor responsible for an innovation that brings undesirable impacts. Who is responsible? Is the research lab that created the technology? Are the engineers that used the technology to create an innovation? Is the company which eventually commercializes the product? To ascribe moral responsibility to someone for an action, several conditions have to be fulfilled. First, the responsible actor is an intentional agent concerning the action. Second, the action resulting in the outcome has to be voluntary. Third, s/he has to know or can have known the outcome of her/his action. Fourth, there is a causal connection between the agent's action or inaction and the consequences observed, and fifth the actor in some way contravenes a norm (Doorn 2011). It is not difficult to imagine that in the uncertain, (frequently) globalized, multi-actor, knowledge-poor context of innovation, these conditions are hardly met. Therefore, regulations seem of little help to embed responsibility issues through the innovation process and to increase the odds of generating innovation outcomes which embody the necessary values for ensuring its ethical acceptability, social desirability and sustainability (von Schomberg 2013).

Therefore, if emerging technologies and innovation are the sources of ethical, social, economic and environmental concerns and regulations are not a suitable mechanism to avoid the appearance of undesirable impacts resulting from innovation, how to ensure that responsibility issues are considered through the innovation process? How to embed in innovation those values which could enhance its sustainability? Does the literature offer useful *tools* for supporting firms in generating innovation outcomes which can be ethically acceptable, socially desirable and sustainable? All these questions are interesting and unsolved challenges which are the focus of this investigation.

1.3 Research objective and questions

Because of increasing complexity and ability of modern technologies to produce far-reaching and long-lasting effects, there are growing political and scientific interests for promoting a more responsible approach to innovation (Owen, Macnaghten et al. 2012). The above discussion has highlighted that innovations can be the sources of relevant ethical, social, economic and/or environmental concerns if they are not developed and launched responsibly. On the other hand, it has been stressed that regulations do not warrant the generation of innovation outcomes which can be safely adopted by society. Therefore, it is necessary that those involved in innovation, and especially firms as the most relevant actor in the innovation enterprise, adopt a more responsible attitude toward innovation. But, how can firms generate innovation in a more responsible manner? This question would guide this research and has helped me to set out its main objective as follows:

- This research aims to propose and validate a framework for helping firms to innovate more responsibly.

To help achieve the above objective, this has been structured around a number of questions that I will explain below.

To help firms to generate responsible innovation, it seems necessary first to clarify what the concept of 'responsible innovation" may mean. This need leads to the first research question:

1. Which definition of the concept of innovation can become a working definition for this research?

Apart from a definition, to achieve the research objective would require exploring the existing literature on innovation in order to find theories or models of innovation which can provide a suitable framework to support firms to innovate more responsibly. This leads to the second research question of this dissertation:

2. How could responsibility issues be embedded through innovation processes to facilitate the generation of responsible innovation according to existing theories and models of innovation?

The answer to research question 2 may provide a theoretical framework consisting of certain mechanisms that literature suggests for considering responsibility issues through innovation processes. Hence, to achieve the research objective stated above, a next step would be to find empirical evidence that confirm (or reject) the usefulness of the theoretical framework for innovating responsibly. The testing of the theoretical mechanisms leads to the following research question:

3. How has responsible innovation been deployed at the firm-level so far?

Finally, the analysis of empirical evidence in relation to the theoretical framework may provide a list of potentially useful mechanisms to support firms in their effort to innovate more responsibly. This leads to the last research questions, which should help achieving the research objective of this dissertation:

4. Are mechanisms to support firms to innovate more responsibly confirmed through empirical evidence?

Briefly, research questions 1 and 2 would require the review of literature in search of suitable concepts, theories and models that can be useful for defining and explaining responsible innovation. On the other hand, research questions 3 and 4 refer to the empirical part of this research. They have been proposed to confirm (or reject) whether mechanisms suggested by literature can be useful for embedding responsibility issues through the innovation process and helping firms in their attempts to generate innovation outcomes which can be safely adopted by society.

1.4 Research approach

The focus of this research is on exploring how innovation processes can be deployed in order to generate responsible innovation. For that I intend to determine what mechanisms may enable the embedding of responsibility issues through the innovation process. This requires a research approach in which innovation processes and their outcomes are studied in such a way that the mechanisms contributing to the shaping of innovation can be identified and explained.

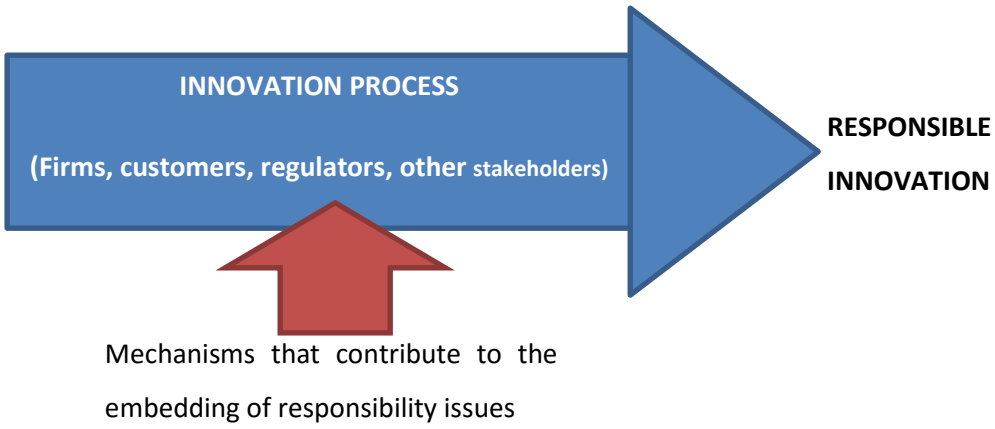

Figure 1. The innovation process and the responsible outcomes (Source: Own elaboration)

It has been considered that an empirical case study approach would be the most suitable to achieve the aim of this thesis. The selection of this particular research approach is due to the characteristics of the phenomena under study: innovation processes. An innovation process can be considered as a complex

phenomenon whose boundaries cannot be clearly distinguished from the context. To understand these kind of phenomena, case study is a suitable and widely used research strategy (Yin 2003).

On the other hand, to investigate how responsible innovation can be generated it would be interesting to explore how existing innovations embedding certain values for sustainability were created and deployed in the past. Therefore, this research would require the selection of innovation processes whose outcomes are characterized by embodying certain values which make them acceptable, desirable and sustainable. It is through studying several of these cases that this researcher expects to find common patterns that enable to explain how responsible innovation can be deployed.

In this research, responsible innovation is traced in the car industry. This industry is an important source of innovations and, in the last years, several of them are clearly promoting a more sustainable road transportation system. Therefore, it is expected that the investigation of certain innovations created by the car industry would provide important insights about how responsible innovation is generated in industrial and international contexts.

This research has been structured as follows (see Table 1). First, a review and analysis of existing definitions, models and approaches of innovation are conducted. Based on this, a working definition and a theoretical framework for responsible innovation are proposed. This is followed by presenting the research design and methodology adopted to conduct this research. Coming up next, three case studies from the car industry are analysed using a qualitative research approach. The collection of data is done through different methods, such as semi-structure interviews, participant observation, field notes and document analysis. Then, the cases are compared and propositions revisited. Finally, conclusions and recommendations are proposed.

Table 1. Overview of research steps and content of this thesis

Activities	Content
Step 1: Stating research topic and proposing a suitable research approach	Chapter 1 Introduction
Step 2: Searching for a definition and a theoretical framework for responsible innovation (RI)	Chapter 2 (research questions 1 to 2C) Working definition and Theoretical Framework for RI
Step 3: Research methodology and propositions	Chapter 3 Research Methodology
Step 4: Case studies Case study I: The commercialization of electric vehicles Case study II: The introduction of new Advanced Driver Assistance Systems (ADASs) Case study III: The multi-collision brake system	Chapter 4-6 (research question 3)
Step 5: Cross-case analysis and testing of propositions	Chapter 7 (research questions 4)
Step 6: Drawing conclusions, providing research recommendations and reflections	Chapter 8 Conclusions, recommendations and reflections

Source: Own elaboration

1.5 Research Relevance

This research may improve our knowledge on how firms can innovate in a more responsible manner. It aims at enhancing the understanding of the mechanisms and factors that need to be considered throughout the innovation process to facilitate the generation of innovation outcomes which are ethically acceptable, socially desirable and sustainable. Thus, this study may shed light on how the actors involved in the generation and commercialization of innovation can organize their innovation processes for enhancing the competitiveness of their organizations while avoiding negative impacts upon socio-economic and/or ecological systems.

It is expected also that this research will also contribute to the understanding and theoretical development of the emerging concept and approach of responsible innovation.

1.6 Outline of this thesis

This chapter has focused on an introduction to the research including the research problem, the research aim and questions for this dissertation.

Chapter 2 encompasses an extensive review of different definitions, models and approaches of innovation, including: Lineal and Interactive models, Innovation System Models, Open Innovation Models, Sustainable Innovation approach and Responsible Innovation approach. Based on this, the chapter develops a working definition of responsible innovation and a theoretical framework for understanding how firms can innovate more responsibly.

In Chapter 3, the research design and methodology is presented. In this chapter, a set of propositions are developed based on the theoretical framework adopted for this research. Further, it justifies the selection of cases that are used to conduct the empirical research part of this thesis.

In Chapter 4-6, three innovation processes are presented and analysed in order to uncover how responsibility issues were considered through the innovation process. Chapter 4 focuses on an innovation process for the commercialization of electric vehicles (EVs) in Spain. Thus, it deals with an innovation which was created to promote a more environmentally friendly mobility. Chapter 5 evaluates how three Advanced Driver Assistance Systems (ADASs) were selected and implemented in new vehicles in order to enhance road safety. Then, Chapter 6 analyses the innovation process that created a new safety system called Multi-Collision Brake (MCB).

In Chapter 7 all three cases are analysed jointly and used to evaluate the propositions suggested in Chapter 3.

Finally, Chapter 8 presents the conclusions about how to foster responsible innovation at the firm-level, suggests recommendations for further research and reflections about RI.

2 Theoretical framework

2.1 Introduction

For more than fifty years, the scholars have developed and proposed theories, models and approaches of innovation to understand, explain and support the management of the innovation enterprise. Existing Systems and Process based innovation theories and approaches enable firms in different aspects for identification and enrichment of innovative ideas and bringing them to the market as new products, services, processes or ways of organizing. However, system theories such national systems of innovation (Freeman 1987; Nelson 1988; Niosi, Saviotti et al. 1993), sectoral systems of innovation (Breschi and Malerba 1996; Malerba 2002) and technological systems of innovation (Carlsson and Jacobsson 1997; Hekkert, Suurs et al. 2007; Surrs and Hekkert 2009) have created a deficit for firms to guide their innovation strategy and innovation process. Recent process based theories, such as Open innovation (Chesbrough 2003), may offer more guiding support for the generation of innovation in increasingly complex environment, in which customer values are constantly evolving, there is fierce competition and regulations get more and more stringent. The question remains whether Open innovation and other existing theories and approaches of innovation may provide a suitable framework for supporting firms in their efforts to embed in innovation the responsibility issues, or put another way, to help firms to generate innovation outcomes which are commercially-sound, ensure high levels of protection of human health and the environment, and are socially desirable or, at least, socially acceptable. In fact, existing theories, models and approaches of innovation may be of limited help to provide an answer to the following questions: How to address the issues of accountability or responsibility for new Research, Development and Innovation (RDI)? How to embed the different values through innovation process so that innovation outcomes are commercially-sound, environmentally-friendly as well as socially desirable or, at least, socially acceptable? How to ensure that new innovation process results in sustainable (socially, economically and environmentally) innovation? How could responsibility issues be embedded through innovation processes to facilitate the generation of responsible innovation? And, how responsible innovation could be deployed at the firm-level?

This chapter would attempt to overcome above conceptual and theoretical challenges and shortcomings related to how to support firms to innovate more responsibly. For that, the concept of responsibility would be explored in Section 2.2 to indicate what may mean and imply when applied to innovative firms. Based on that understanding, criteria would be defined to support the search for a working definition and a theoretical framework suitable for this dissertation. Next, Section 2.3 would be dedicated to review of different definitions of innovation. Further, a working definition of responsible

innovation is proposed for this dissertation. Section 2.4 would be focused on answering the following research questions: How could responsibility issues be embedded through innovation processes to facilitate the generation of responsible innovation according to existing theories and models of innovation? Finally, section 0 would summarize the main conclusions of this chapter.

2.2 A review of the concept of responsibility

The aspect of responsibility for the research problem is linked to innovation which is generated or created by the firms. The firms are not linked to responsibility. Therefore, there is no attempt to understand how much and up to what extent firms are responsible. Hence, how firms can be supported or facilitated by new concepts and approaches for bringing out responsible innovation? In addition, how firms can keep responsibility aspects of innovation as their major focus. To answer these questions, I believe that there is necessary to explore several questions with regard to the concept of responsibility, such as: what is the meaning of the concept of responsibility? What does responsibility mean according to the existing ways of ascribing responsibility? Which aspects of the concept of responsibility may be considered to encourage business organizations to create innovation outcomes which are safe, ethical, environmentally-friendly, and socially desirable or at least socially acceptable? This section would be focused on exploring the concept of responsibility and the different perspectives for ascribing responsibility. The aim is to provide the conceptual foundations which support the search for a definition of responsible innovation as well as a theoretical framework which are suitable to address the research objective of this dissertation.

2.2.1 Responsibility

Responsibility is a concept which has been profoundly discussed and studied in psychology (e.g. (Alicke 2000; Shaver 2012)), moral philosophy (e.g.(Fischer and Ravizza 2000)) , law (e.g. (Hart 2008)) and, in a lesser extent, engineering and technology management (e.g. (Fahlquist 2006; Swierstra and Jelsma 2006; Doorn 2010; Doorn and Fahlquist 2010; Doorn 2011)). Responsibility is a complex, even slippery concept, without an unambiguous definition (Doorn 2011). According to the Dictionary Collins_Cobuild (1997), the concept of responsibility can mean the following:

- If you have *responsibility* for something or someone, it is your job or duty to deal with them;
- Your *responsibilities* are the duties that you have because of your job or position;
- If you think you have a *responsibility* to do something, you feel that you ought to do it because it is morally right or your duty to do it;
- If you accept *responsibility* for something that has happened, you agree that you were to blame for it.

Pennock (1952) provides two additional understandings of the concept of responsibility, one related to accountability and a second one related to explicability. Thus, in the sense of answerability, 'a person is responsible to another for his actions when he can be held to account for them by another'. On the other hand, responsibility as explicability means that 'a person's conduct is responsible it is susceptible to rational explanation and, furthermore, if it is conditioned upon an attempt to obtain the relevant facts, upon deliberation, and upon consideration of, and due regard to, the consequences' (Pennock 1952).

The above depicts that the term responsibility can have different meanings and that people can interpret it differently depending on the context. So, in order to generate a useful understanding of the concept of responsibility in the context of innovation, it may be interesting to explore the meanings of responsibility in related fields. Hence, the main perspectives for ascribing responsibility within the fields of science and technology are outlined hereafter, as well as the implications for innovation and the innovative firm.

2.2.2 Perspectives for ascribing responsibility

Within the field of science and technology, there are three main perspectives for ascribing responsibility: *a merit-based*, *a rights-based* and *a consequentialist* perspective. Each perspective provides different interpretations or views of the concept of responsibility. Next, I will review each of them and point out to the potential meanings and implications that they can have when applied to innovation.

Under the merit-based perspective, to ascribe responsibility to a company P for an event A means that P is causally involved in bringing about P and, therefore, she can be blamed or praised for that. In this case, being morally responsible for P involves reactive attitudes (e.g. it may involve some kind of punishment, like a fine or imprisonment for one or more of the firm's managers or employees). To ensure fairness, under the merit-based perspective the ascription of moral responsibility is only warranted if the reactive attitudes and their consequences are deserved. This implies that certain conditions have to be met before it is fair to ascribe responsibility to someone. These conditions are: 1) Moral agency (i.e. the responsible actor is an intentional agent concerning the action); 2) Voluntariness or freedom (i.e. the action resulting in the outcomes was voluntary); 3) Knowledge of the consequences (i.e. the actor knew, or could know, the outcome); 4) Causality (i.e. the action of the actor contributed causally to the outcomes) and 5) Transgression of a norm (i.e. the actor in some way contravened a norm). Under this perspective, responsibility is mainly ascribed retrospectively (who is to be blamed for A?), although it could also be ascribed in a forward-looking manner (Doorn 2011). Here, the forward-looking ascriptions of responsibility are linked to the duty of (reasonable) care. This means that an

innovator or company would be considered as acting responsibly with regard to innovation if he or she explores the foreseeable and unforeseeable impacts resulting from innovation and attempts to eliminate the undesirable ones before the innovation is deployed.

On the other hand, the right-based perspective of ascribing responsibility stresses the individual right of people to be safeguarded from other's actions. This is known as the principle of no harm. Under this perspective, actions conducted by a company P are right if and only if: either there are no (possible) consequences for others, or those who would *suffer* them have consented to the actions after having been fully informed of the possible consequences. Therefore, under this perspective an innovator or company is said to act responsibly regarding innovation if he or she asks for consent to all affected people before an innovation is deployed.

In the last of the three perspectives, the consequentialist, responsibility is ascribed for instrumental reasons, i.e. responsibility is ascribed to trigger a reactive response that would likely lead to a desired outcome, such as improved behaviour by the firm. In this approach, the criterion for ascribing responsibility is *efficacy* rather than fairness (main criterion for the merit-based perspective) or the informed consent (main criterion for the rights-based perspective). So, under this perspective the morally optimal responsibility ascription is that that yields the best consequences (Doorn 2011).

Under the consequentialist-based perspective responsibility is mainly ascribed in a forward-looking or prospective way. So, responsibility ascriptions have to do with future events, bringing them about or preventing them from occurring, and not with who is to be blamed for past events (Fahlquist 2006). If applied to innovation, firms would be expected to act according to duties and dictated actions but also, and importantly, according to general principles (e.g. to create "a safe road traffic environment"), which are related to a desirable particular state of affairs (Fahlquist 2006).

From a consequentialist perspective, an innovation would be "right", in the sense that would be socially desirable or at least socially acceptable, if outcomes have been created by taking into account the potential implications for society (e.g. upon human health and the environment) from the outset of the innovation process. This does not mean that a "responsible" or right outcome would be that in which all risks have been completely eliminated, what may probably be impossible to achieve, but that foreseeable risks have been considered throughout the innovation process. This implies that in certain occasions, and after deliberation among stakeholders, a potential risk may be accepted as is since the (societal) costs of preventing it can be higher than the (societal) costs of accepting it (Doorn 2011).

Based on the different perspectives outlined above, the concept of responsibility when applied to innovation and innovative firms can involve the following:

- Firms act responsibly when they foresee the intended and the unintended impacts upon society (e.g. upon human health and the environment) resulting from innovation outcomes before they are deployed in order to avoid or reduce them up to levels which are compatible with stakeholders' values;
- Responsible firms act according to established social and legal norms;
- Responsible firms act according to social expectations and/or principles that reflect what society considers as a desirable state of affairs or outcome;
- Responsible firms engage with stakeholders in order to assess whether innovation would be acceptable or not. Responsible firms would not deploy an innovation which can produce negative impacts on others without agreeing with them the level of risk that is acceptable;
- Firms may be considered as acting responsibly if they work to embed certain values in innovation to make it socially desirable or at least socially acceptable.

2.2.3 Criteria for assessing definitions, models and approaches of responsible innovation

Reviewed perspectives of ascribing responsibility within the fields of science and technology have provided certain understandings about what responsibility may mean and imply when it is applied to innovation and innovative firms. Based on these understanding, the following criterion is defined to support the search for a suitable working definition of responsible innovation:

I. The definition should state social expectations and/or principles that guide the innovation process toward what society considers as desirable or at least acceptable (i.e. what society would consider as "right" or responsible)

In a similar vein, the following criteria are defined to assess existing models and approach of innovation, in order to facilitate the search for a theoretical framework for innovating responsibly at the firm-level:

A. It should support firms to understand what would be "right" from the society's perspective in their context;
B. It should involve mechanisms which allow firm to anticipate risks resulting from innovation before it is commercialized to avoid, or reduce up to socially acceptable levels, undesirable impacts upon socio-ecological systems;
C. I should provide mechanisms which allow the integration of stakeholders in order to assess the desirability or acceptability of innovation outcomes, and to agree, when needed, the levels of risks that would be acceptable;

D. It should help firms to innovate according to certain values to make the innovation outcomes workable and "right" (i.e. socially desirable or at least socially acceptable),
E. I should help firms to design and develop their innovation processes in order to generate outcomes responsibly.

2.2.4 Conclusions

In this section, the concept of responsibility has been reviewed in order to develop an understanding of what can mean and imply this concept. The review of the concept revealed that it is a complex concept, not free of ambiguity. Responsibility can be interpreted differently depending on the context in which it is used. Therefore, three perspectives of ascribing responsibility have been revised in order to clarify what responsibility could mean and imply when applied to innovation and innovative firms: the merit-based, the rights-based and the consequentialist-based perspective. The review of the three perspectives allowed generating a more concrete understanding of the concept of responsibility regarding the contexts of innovation. For instance, responsible firms would create innovation outcomes by taking into account their potential implications for society (e.g. upon human health and the environment) from the outset of the innovation process. Moreover, firms would be considered as responsible if they engage with stakeholders in order to agree the level of risks that would be acceptable before innovation is deployed. From the uncovered implications of the concept responsibility when applied to innovation, several criteria have been defined. These will be used in the next sections to search for a suitable definition of innovation (Section 2.3) and a theoretical framework that could contribute to achieve the aims defined in this dissertation (Section2.4).

2.3 In search for a working definition of responsible innovation

2.3.1 Introduction

In literature it is possible to find a large number of definitions of innovation and related concepts. Hereafter, several definitions of innovation and related concepts would be reviewed and assessed against the criterion defined in the Section 2.2.3 in order to find a suitable working definition of responsible innovation for this dissertation. Due to the large number of definitions available, first general definitions of the concept of innovation would be assessed in Section 2.3.2.1.Then, a second group of definitions encompassing particular types of innovation would be reviewed in Section 2.3.2.2. Finally, a working definition of responsible innovation would be suggested in Section 2.3.4.

2.3.2 Definitions of the concept of Innovation

2.3.2.1 General definitions of innovation

The concept of innovation has been a subject of scientific inquiry from the Nineteenth-century to the present days, and since then a panoply of definitions have been suggested. Early definition of the concept stated that innovation is the carrying out of new combinations (Schumpeter 1934). These new combinations include the creation of new or improved products, the implementation of new processes, new ways of supplying materials or goods, and new ways of organizing within firms. Freeman (1982) defined innovation as 'the first commercialization transaction involving the new product, process, system or device'. On the other hand, Nelson and Rosenberg (1993) defined it as the process by which firms master and put into practice product designs and manufacturing process that are new to them. Drucker (1985) referred to innovation as 'the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or service. It is capable of being presented as a discipline, capable of being learned, capable of being practised'. Further, Baregheh, Rowley et al. (2009) has defined innovation as a 'the multi-stage process whereby organizations transform ideas into new/improved products, services, or processes, in order to advance, compete and differentiate themselves successfully in their marketplace'. Innovation can also refer to 'a process that follows invention, being separated from invention in time. Invention is the creative act, while innovation is the first or early employment of an idea by one organization or a set of organizations with similar goals' (Becker and Whisler 1967). Recently, Chesbrough (2003) coined the term open innovation to refer to the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively.

2.3.2.2 Sustainable Innovation and Responsible Innovation

The concept of innovation is in constant evolution. New terms like eco-innovation, sustainable innovation, environmentally-oriented innovation as well as responsible innovation have emerged in the last decades to conceptualise innovation whose outcomes embody certain values[1] or features.

In literature, several concepts can be found to denote innovation that aims to sustainable development (Brundtland 1987), such as eco-innovation, sustainable product innovation, sustainable innovation or environmentally-oriented innovations. Hereafter, the concept sustainable innovation would be used to

[1] Throughout this Thesis, the concept value will be used to mean: 1) the core set of beliefs and principles deemed to be desirable (by groups) of individuals (Joyner, B.E. et al. 2002), or 2) the perceived gain that a customer assigns to a products in the purchase process.

refer to innovation that supports sustainable development, just for convenience reasons, although different authors have used different concepts to refer to this kind of innovation.

Sustainable innovation (SI) has been defined as new products and processes that provide customer and business value and significantly decrease environmental impacts (Fussier 1996). Similarly, Johansson and Magnusson (1998) defined sustainable innovation as new products and processes that provide customer value, while using fewer resources and resulting in reduced environmental impacts. On the other hand, Rennings (2000) defined SI as new or modified processes, techniques, practices, systems and products aimed at preventing or reducing environmental damage. Sustainable innovation has been also defined as the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution, and other negative impacts of resource use (including energy use) to relevant alternatives (Buttol, Buonamici et al. 2012). Furthermore, SI can also be understood as a firm's implementation of a new product, process, or practice that significantly reduces the impact of the firm's activities on the natural environment (Varadarajan 2015).

On the other hand, the concept of responsible innovation (RI) has emerged recently and several authors have suggested different definitions. For instance, von Schomberg (2013) defined responsible innovation as a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society). RI has also been defined as being caring and ensuring care for certain values for social, economic and environmental sustainability by engaging in anticipation, reflexivity, deliberation, responsiveness and participation for bringing up any change in any idea, product, process, method, way of business, and technology to bring them in specific market or use in specific society (Singh 2012). RI is seen as a collective commitment of care for the future through responsive stewardship of science and innovation in the present (Owen, Stilgoe et al. 2013). According to Sutcliffe (2013), RI is innovation that helps fulfil our needs and hopes without compromising the ability of others, now and in the future, to fulfil their own. Another definition of RI conceptualises it as an activity or process which may give rise to previously unknown designs pertaining either to the physical word (e.g., designs of buildings and infrastructure), the conceptual world (e.g., conceptual frameworks, mathematics, logic, theory, software), the institutional world (social and legal institutions, procedures, and organization) or combinations of these, which –when implemented- "*expand the set of relevant feasible options regarding solving a set of moral problems"* (van den Hoven 2013).

2.3.3 Differences and limitations of definitions of innovation

The review of general definitions of innovation done in Section 2.3.2.1 illustrates that there is no consensus on the understanding of the concept of innovation. Such a diversity in the definition of innovation is a challenge for those who research and practice innovation (Ettlie, Bridges et al. 1984). But, what are the key differences among definitions of innovation? And, could any of the above definitions become the working definition of this dissertation? If not, why?

The main differences among definitions reviewed in Section 2.3.2.1 entail whether innovation is seen as a static or dynamic concept and the scope of the outcomes. Thus, some authors show innovation as static (Drucker 1985) although most defined as a process or set of activities (Becker and Whisler 1967; Nelson and Rosenberg 1993; Baregheh, Rowley et al. 2009).

With regard to the scope of these definitions, Becker and Whisler (1967)'s definition does not indicate what is the nature of the outcomes of innovation (product, process or something else). Other authors limit the scope of innovation to certain outcomes, such as a business and service (Drucker 1985), or product designs and manufacturing processes (Nelson and Rosenberg 1993). Others expand innovation to entail also new ways of supplying and organizing (Schumpeter 1934), new systems and devices (Freeman 1982), or new services (Baregheh, Rowley et al. 2009).

With regard to the questions: could any of the definitions become the working definition of this dissertation? If not, why? The definitions reviewed in Section 2.3.2.1 present a key shortcoming that would not recommend their adoption as working definition for this research. This shortcoming relies on the fact that none of the above definitions explicitly indicate what is or means a responsible or socially desirable innovation. Although, several of the above definitions show innovation as a process or set of activities (Schumpeter 1934; Freeman 1982; Nelson and Rosenberg 1993; Baregheh, Rowley et al. 2009) aimed at creating and commercializing new or improved products, services, etc., none does include any reference to the normative direction or general principle that firm should follow to ensure that outcomes could be considered as "right" Therefore, the definitions reviewed in Section 2.3.2.1 offer little guidance for firms to innovate responsibly and, consequently, are not considered as the most suitable for this dissertation.

With regard the group of definitions of Sustainable Innovation (Section 2.3.2.2) it seems that there is a certain consensus among different scholars around this concept. The review shows that SI is clearly associated with an outcome (product, process, etc.) that reduces environmental impacts. On the other hand, the review reveals a significant shortcoming which may hinder the usefulness of any definitions of SI as a working definition for this Thesis. In particular, SI refers to outcomes which are socially desirable

or at least socially acceptable outcomes from an environmental viewpoint, while other social, moral and ethics aspects and values are neglected. Therefore, most of SI definitions do not provide enough principles and criteria to guide firms to innovate responsibly. Based on these arguments, the reviewed definitions of SI are considered as less suitable for the purposes of this research.

With regard to definition of RI (Section 2.3.2.2), the review illustrates that the concept of RI is still evolving and there is not a consensus among scholar about its conceptualization. Interestingly, and unlike SI or more general definitions of innovation, several definitions of RI provide general principles which indicate what society may consider as a responsible behaviour or outcome. From the definition suggested by von Schomberg (2013), it could be deducted that a responsible innovator or firm would attempt to generate products which are (ethically) acceptable, sustainable and socially desirable[2]. On the other hand, Singh (2012)'s definition suggests that a responsible innovation outcomes would ensure care of certain values for achieving the social, economic and environmental sustainability.

Despite these interesting strengths, the definitions of RI reviewed show certain limitations in their scope, are ambiguous or impose certain conditions which may hinder their applicability at the firm-level and, therefore, their usefulness as a working definition for this dissertation. For instance, von Schomberg (2011)'s definition states that RI is *a transparent, interactive process*. Is it possible to expect that business organizations would carry out *transparent* innovation processes? Certainly, some degree of transparency would be necessary to innovate responsibly. For instance, it would be expected that responsible firms are transparent about the risks resulting from innovation in order to inform stakeholders and to collectively deliberate whether it would be responsible or not to deploy innovation. But much information about innovation may not be disseminated among stakeholders for confidentiality reasons, what clearly reduce the transparency of the process. Therefore, RI may not be a *fully* transparent process, but rather a process in which fluid communications and trust among stakeholders would be desirable and necessary.

Regarding the definition suggested by Singh (2012), its main shortcoming is that it includes how to achieve RI, something it may not be necessary to state in a definition. On the other hand, Owen, Stilgoe et al. (2013) define RI as a *commitment of care for the future,* a concept too general that limits the usefulness of the definition as it introduces certain ambiguity about what firms should do or pursue in order to act responsibly.

[2] Von Schomberg (2013) suggests that responsable products ensure a high level of protection to the environment and human healt, are sustainable and socially desirable.

In Sutcliffe (2013)'s definition, the shortcoming or limitation is that the term 'innovation' is used to define Responsible Innovation. Finally, the van den Hoven (2013)'s definition refers to innovation as *unknown designs that expand the set of relevant feasible options regarding solving a set of moral problems*. This view is again too ambiguous as it does not provide a clear general principle or guideline that can be used by firms to orient their efforts towards a more responsible approach to innovation.

Summarizing, the review of definitions of innovation, open innovation, sustainable innovation and responsible innovation reveals certain limitations and shortcomings which limit their usefulness as a working definition for this dissertation. The main limitations and shortcomings identified are the following:

- Innovation is seen as a static and a dynamic concept. It is needed to clarify if responsible innovation would refer to *the outcomes of a process* or to the *process.*
- Some definitions are ambiguous, i.e. they does not clearly state what innovation *is*;
- Definitions have a limited scope, i.e. innovation outcomes are limited to products and processes, for instance, and
- Definitions do not state a general principle that can guide firm to act responsibly.

The next section would be focused on developing a new definition on responsible innovation.

2.3.4 Developing a working definition of responsible innovation

To facilitate the development of a new definition, Table 2 presents in a chronological order the main components of the reviewed definitions. Table 2 also presents the general principle that is implicitly or explicitly stated in each definition and which can guide firms to innovate more responsibly. Finally, the main commonalities found in the definitions are indicated.

Table 2. Definitions of Innovation, Main Components and Commonalities

Authors	Main Components	General principle	Key Concepts from all Definitions
Schumpeter, J. 1934	New or improved product, implementation of new processes, new ways of supplying, and new ways of organizing	No stated	New Product Process Service Organization Idea Change Opportunity Firm Knowledge Environment Ethical acceptability Sustainability Social desirability Care
Becker and Whisler 1967	First or early employment of an idea	No stated	
Freeman, C. 1982	First commercialization involving new product, process, system or device	No stated	
Drucker, P. 1985	Means to exploit change as an opportunity for a different business or service	No stated	
Nelson and Rosenberg, 1993	Process aiming at creating product designs and manufacturing processes new to the firm	No stated	
Fussier, C., 1996	New product or process that decreases environmental impacts	Improved environmental performance of innovation outcomes	
Johansson and Magnusson, 1998	New product or process that provide customer value with reduced environmental impacts	Improved environmental performance of innovation outcomes	
Rennings, K., 2000	New or modified process, technique, practices, system and product aimed at reducing environmental damage	Improved environmental performance of innovation outcomes	
Chesbrough, H., 2003	Use of internal and external knowledge	No stated	
Baregheh, A. et al., 2009	Process that transforms ideas into new/improved products, services or processes	No stated	
Buttol, Buonamici et al., 2012	Production, assimilation or exploitation of a product, process, service or management or business method with reduced environmental impacts	Improved environmental performance of innovation outcomes	

Authors	Main Components	General principle	Key Concepts from all Definitions
Singh and Kroesen, 2012	Taking care and ensure care of certain values for sustainability	Social, economic and environmental sustainability	
Owen, Stilgoe et al., 2013	Collective commitment of care for the future	Care for the future	
Sutcliffe, H., 2013	Innovation that fulfil our needs and hopes without compromising the ability of others	Non compromising the ability of others to fulfil their needs	
Van den Hoven, 2013	Activity or process that give rise to new designs	Expanding the set of relevant feasible options regarding solving a set of moral problems	
Von Schomberg, R., 2013	Transparent, interactive process	Ethical acceptability, sustainability and societal desirability of innovation processes and outcomes	
Varadarajan, R., 2015	Implementation of a new product, process, or practice that reduces environmental impacts	Improved environmental performance of innovation outcomes	

Source: Own compilation from the definitions in section 2.3.2

2.3.4.1 Adopted definition

A first issue to decide regarding a suitable definition for the concept of responsible innovation to address the research objective of this dissertation is whether this should refer to the static or the dynamic understanding of the concept of innovation. Both understandings are widely used, both in business and scientific areas. Therefore, to facilitate the decision making with regard to this issue, it can be interesting to reflect on *what may be considered as responsible* when we are talking about innovation: is it the outcome or the process which can be considered as responsible? The concept of responsibility is normally ascribed to an individual or collective of individuals. It is people who are said to be responsible and/or act responsibly or irresponsibly. Thus, we do not usually use the concept of responsibility to refer to objects (e.g. it would not be very common to state 'it is an irresponsible chair'). But, we can refer to certain abstract concepts as responsible or irresponsible. So, we can say for instance "that was an irresponsible decision". In these cases, we know that the decision was made by someone and that the consequences of that decision are against certain values, rules and/or social norms. With regard to innovation, something similar may apply. The outcomes of innovation may be referred as responsible if those in charge of their creation acted responsibly. Or an innovation process may be referred as responsible if those involved acted responsibly so that they generated outcomes which could be considered as 'right' by societal actors. Therefore, we may use the concept of responsible innovation to refer to the process of innovation, but we can use this concept to refer to the outcomes of the process too. This allows but also requires defining somehow what we refer in both cases.

Based on the reviewed definitions of innovation and their commonalities as well as the uncovered general principles to guide firms to act responsibly, a working definition of the concept of 'responsible innovation' for this Thesis is proposed hereafter:

"Responsible innovation refers to a process in which those involved (firms, research institutions, regulators, etc.) care and ensure care for certain values for social, economic and environmental sustainability for bringing a new or improved product, process, service, method or way of organizing in a specific market or context."

The above definition sees thus responsible innovation as a dynamic concept as it clearly states that responsible innovation is a *process*. Further, it states the main distinctive characteristics of responsible innovation: it is a process characterised by the efforts of those involved in for *caring and ensuring care for certain values for social, economic and environment sustainability*. Moreover, it suggests a general principle that indicates what society considers as morally responsible. This general principle provides guidance to firm's actions: to achieve the goals of *social, economic and environmental sustainability*.

Sustainability is proposed as an overarching value, which entails both global and context-specific values. This allows using the definition in developed and developing countries. Importantly, the definition does not state how the general principle should be achieved, what provides flexibility to apply those actions that are more convenient to achieve the desirable outcomes according to the context. On the other hand, the definition states the purpose or outcome of any responsible innovation process: *bringing new or improved product, process, service, method or way of organizing in a specific market or context.* This conceptualization has two advantages: first, it does not limit the scope of innovation to products and processes, but entails new services, ways of organizing or working. Secondly, the definition can be used for commercializing new products, services, etc. as well as for adopting and implementing changes within firm contexts through acts of responsible innovation.

Once the concept of responsible innovation has been defined, it is then possible to state what I will refer as a responsible outcome:

"A responsible innovation outcome is a new or improved product, process, service, method or way of organizing brought in a specific market or context and that embodies certain values for social, economic and environmental sustainability"

With the above definitions I have paved the way for beginning the search of mechanisms to help firm to deploy responsible innovation. The next section reviews existing theories, models and approaches of innovation. From those theories, models and approaches of innovation a theoretical framework would be suggested which can be helpful to help firms in their attempts to innovate responsibly.

2.4 Theoretical Framework for Responsible Innovation

In order to support firms to innovate responsibly, a theoretical framework is required. In this section, different theories, models and approaches of innovation are reviewed and assessed in order to find a suitable theoretical framework which could help firms in their efforts to innovate more responsibly. This section begins with a review of well-developed and accepted theories, models and approaches for innovation (Section 2.4.1). Next, it presents, assesses and justifies the adoption of a new and emerging approach of innovation, called Responsible Innovation, as the basis for a Theoretical Framework for this dissertation (Section 2.4.2). In Section 2.4.3, the Theoretical Framework selected is further developed to address the following research question: How could responsibility issues be embedded through innovation processes to facilitate the generation of responsible innovation?

2.4.1 Review of Theories, Models and Approaches of Innovation

2.4.1.1 Early models of innovation

2.4.1.1.1 The linear Model

The lineal model of innovation is one of the first theoretical frameworks developed by describing the relationship of science, technology and the diffusion of new products and services. This model describes innovation as a sequence of functional activities consisting of basic research, applied research, development, production and diffusion (Godin 2006).

Figure 2: Activities explaining innovation in the Linear Model

In this model of innovation, basic research is considered the source of applications and refinements which are then developed and eventually commercialized (Tidd and Bessant 2009). The above model suggests that 'technology push' is the primary driving force explaining technical change (Marinova and Phillimore 2003).

In response to the 'technology push' approach, Schmookler (1966) suggested an alternative linear model in which the anticipated demand was the key driver for innovation (Peters, Schneider et al. 2012). Therefore, and unlike the technology push model, the 'Market pull' model suggests that the marketplace, and not the corporate R&D centres, is the key driving force of technical change. So, this model states that innovation is the result of sequential activities: Market place, Technology Development, Manufacturing and Sales (Marinova and Phillimore 2003)

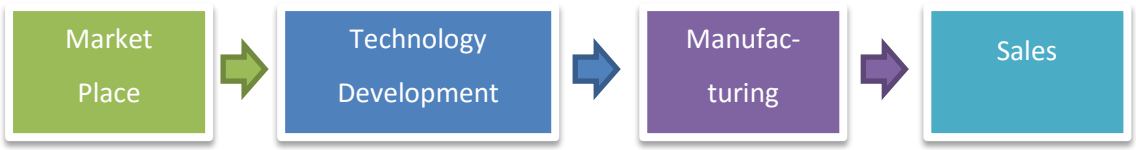

Figure 3. 'Market pull' linear model of innovation (Source: Rothwell (1994))

2.4.1.1.2 The interactive model

The above linear models were challenged in the 70s and 80s because of their simplistic view of the process of innovation (Nemet 2007). Therefore, there was a need for better understanding and description of all the aspects and actors involved in the innovation process (Marinova and Phillimore

2003). Rothwell and Zegveld (1985) suggested the interactive model as an attempt to bring together the technology-pull and market-pull approach and provide a more comprehensive model of innovation (Marinova and Phillimore 2003). The interactive model states that innovation can be seen 'as a complex net of communication paths, both intra-organizational and extra-organizational, linking together the various in-house functions and linking the firm to the broader scientific and technological community and to the marketplace' (Rothwell and Zegveld 1985). Core to this model is the emphasis on the variety interactions among firms, the marketplace and institutions providing knowledge that are necessary for the success of innovation.

2.4.1.1.3 Conclusions

Could the linear and interactive models provide a suitable framework to support business organizations to innovate responsibly? The above models provide a simple view of the innovation process, which can be helpful for illustrating and explaining in a straightforward manner the complex process of innovation. But, the revised models do not provide an analytical framework that stimulates firms to innovate towards any specific direction, to foresee and assess risks resulting from innovation in the innovation process or to understand what is socially desirable in a certain context. Therefore, it is necessary to look for alternative and more complex models.

2.4.1.2 Innovation system models

2.4.1.2.1 Introduction

The concept 'innovation system' was first introduced by Lundvall (1985) and, since then, it has been widely used as an analytical concept among scholars and policy makers all over the world.

Edquist (2010) defined systems of innovation as "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations". In the last three decades, the concept of innovation system has evolved into several concepts which focus on different levels of the economy (Lundvall, Johnson et al. 2002). This includes national innovation systems (NIS) (Freeman 1987), regional systems of innovation (RIS) (e.g. Silicon Valley), sectoral systems of innovation (SSI) (Breschi and Malerba 1996; Malerba 2002) and technological systems of innovation (TIS) (Carlsson and Jacobsson 1997; Hekkert, Suurs et al. 2007). Innovation system theories are rooted in evolutionary economic theorizing on socio-technical change. They stress phenomena such as path dependency, lock-in, interdependence, non-linearity and coupled dynamics for explaining technological change and economic growth (Markard and Truffer 2008). The system innovation approach considers innovation as an interactive process among a wide variety of actors (Malerba 2002). Core to all innovation system theories is describing and understanding how knowledge is created, diffused and

used by a network of actors to generate innovation and economic growth (Carlsson, Jacobsson et al. 2002).

Hereafter, national, sectoral and technological systems of innovation are reviewed in order to assess whether any would fit with the research problem and objective of this dissertation.

2.4.1.2.2 National System of Innovation

Freeman (1987) defined national innovation systems of innovation as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies'. Key elements of the NIS approach to innovation are actors, learning processes and institutions. Freeman (1987) included as institutions the units in charge of R&D activities (e.g. universities and companies), other social innovations (e.g. Fordism or just-in-time systems of manufacturing) and political institutions that determine how available resources are managed and organized, both at the firm and national level. (Nelson 1988) argued that in NIS, government policy at the national level plays a key role for developing homogeneity and linkages among national agents of innovation.

In the concept of NIS, the social acceptance of innovation outcomes is largely neglected (Quist 2007). Instead, the focus is the network of institutions operating at the national level and on explaining NISs, and the difference between them, by characterising the units of the system, measuring the flows among units as well as measuring performance of NISs (Niosi, Saviotti et al. 1993).

2.4.1.2.3 Sectoral systems of innovation

The sectoral system of innovation describes 'a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products' (Malerba 2002). The notion of sectoral system, as proposed by Malerba (2002), emphasises the structure of the system in terms of products, agents, knowledge and technologies and on its dynamics and transformation.

Sectoral systems encompass the following basic elements (Malerba 2002):

- *Products:* They encompass the set of new and established products that are created, produced and sold by the agents within a sectoral system of innovation. .
- *Agents*: Agents include firms and non-firm organizations (e.g. universities, financial institutions, etc.), individuals as well as sub-units of firms (e.g. R&D departments) or aggregation of actors, such as firms' consortia. Agents interact through processes of communication, exchange, co-operation, competition and command.

- *Knowledge and learning processes*: The knowledge base differs across sectors and it is a key determinant of the innovative activities, the organization and the behaviour of firms and other agents within a sector.
- *Basic technologies, inputs, demand, and the related links and complementarities.* Links and complementarities include interdependencies among vertically and horizontally related sectors. Interdependencies and complementarities define the boundaries of a sectoral system. They may be at the input, technology or demand level. They may concern innovation, production and sale.
- *Mechanisms of interaction both within firms and outside firms*: These mechanisms involve process of market and non-market interactions.
- *Processes of competition and selection:* The firms' heterogeneity within sectoral systems depends on two processes, the process of variety creation and the process of selection. These two processes shape the industrial dynamics and explain the differences across sectoral systems.
- *Institutions*: These entail standards, regulations, labour markets and so on. Institutions shape the interactions among the agents forming the sectoral system.

According to SSI theories, the co-evolution of the above elements determines the change and transformation of a sectoral system over time (Malerba 2002).

Apart from the national and sectoral systems of innovation, other concepts emphasising the systemic characteristics of innovation have emerged over the last decades (Lundvall, Johnson et al. 2002). One of those concepts is technological system of innovation (Carlsson and Jacobsson 1997; Hekkert, Suurs et al. 2007), which is reviewed in the next subsection.

2.4.1.2.4 Technological systems of innovation

The technological system of innovation is an analytical construct developed to illustrate and understand the system dynamics and performance of socio-technical systems associated with the development, diffusion and used of a particular technology (Bergek, Jacobsson et al. 2008). In the TIS approach, the system boundaries are not delimited by geographical boundaries, as in national and regional systems of innovation. Instead, TISs focus on the components responsible for the development of *generic technologies* as well as on the complementary components that have an influence on the innovation process for those technologies (Carlsson, Jacobsson et al. 2002; Bergek, Jacobsson et al. 2008). The system boundaries may then be circumscribed to a sub-system of a sectoral system or may encompass components of different sector systems (Bergek, Jacobsson et al. 2008).

Unlike other innovation system approaches, in which system structures are regarded as static, TISs studies may focus on understanding the dynamics that induce or block the successful development of emerging innovation systems around specific technologies, such as sustainable energy technologies (Jacobsson and Bergek 2004; Surrs and Hekkert 2009). The TIS approach provides thus a dynamic framework suitable for understanding processes underlying the formation of a system. The dynamics of a system can be unveiled by keeping track of system functions as they unfold through time (Surrs and Hekkert 2009). Systems functions are defined as the contribution of a component or a set of components to the overall function of the innovation system (Johnson 2001). They are considered the activities, or set of activities, that influence the build-up of TIS (Surrs and Hekkert 2009).

TIS approach offers a dynamic perspective and framework to understand and support by generating policy recommendations the development of systems of innovation contributing to sustainable development (Jacobsson and Bergek 2004; Surrs and Hekkert 2009). In line with innovation system approaches, TIS stresses the interactive and systemic nature of the innovation process and the need to create policy instruments which support the formation of new technological innovation systems in order to increase the odds of successful diffusion of new (sustainable) technologies (Surrs and Hekkert 2009).

2.4.1.2.5 Conclusions on innovation system models

In this section, several innovation systems theories have been revised. The innovation system literature illustrates innovation as an interactive process in which networks of actors create, modify, use and diffuse innovation outcomes. The level of analysis varies depending on the adopted approach, from a nation or region to a sector and group of actors and institutions related to a specific technology.

With regard to the question of whether innovation system theories and models can support to innovate responsible at the firm-level, they do not seem to provide a suitable framework. The main reasons supporting this conclusion are the following: in theories and models of innovation systems, issues such as social desirability and acceptance of innovation outcomes, risks resulting from innovation, values for sustainability and desirability and other responsibility issues are neglected. On the other hand, innovation system theories and models look at companies as black boxes. Then, they do not explain how innovation is developed within firms and, therefore, they do not provide enough guidance on how firms can generate outcomes which embed certain values for enhancing their desirability and sustainability of outcomes. As this thesis aims to explore how responsible innovation can be fostered at the firm-level, process-based rather than system-based theories seem more likely to provide a suitable framework for address the research problem. This guides the search for a suitable framework to the concept of open innovation, coined by Chesbrough (2003). The next subsection would be dedicated to review this model.

2.4.1.3 Open Innovation Model

The concept of open innovation (Chesbrough 2003) is related to other systems of innovation concepts, such as national and regional innovation systems, but differ from the level of analysis adopted. Thus, while the open innovation model looks at the innovation system from within the company, the systems of innovation literature sees companies as black boxes (OECD 2008) to adopt an outsider perspective.

Open innovation means the use of purposive inflows and outflows of knowledge to enhance the firm's innovation performance (Chesbrough 2003). In the open innovation model, the companies' boundaries become a semipermeable membrane that enables innovation to move between the external environment and the companies' internal innovation process (OECD 2008). The permeability of the firm's boundaries is based on three core processes: outside-in, inside-out and coupled processes. The outside-in process refers to internal use of knowledge captured from the external environment (customers, suppliers and other sources). On the other hand, inside out processes refer to the external exploitation of internal knowledge, i.e. bringing internal ideas to market, selling Intellectual Property or transferring ideas to the outside environment. The coupling processes refer to combining outside-in and inside-out processes by creating partnerships/alliances with other actors (Gassmann and Enkel 2004).

So far, the core of open innovation research and literature has revolved around 1) explaining what the concept means in practice (i.e. inbound, outbound and coupled activities), 2) understanding the firm's internal and external context characteristics explaining the strength and direction of open innovation activities, and 3) uncovering the process to open the innovation process as well as the key practices and stages in open innovation processes (Huizingh 2011).

For a firm, the main benefits resulting from adopting an open innovation model may be the following: larger base of ideas and technologies to support the internal innovation activities, reduction of risks associated with innovation, increase flexibility and responsiveness, as well as increase speed of exploitation and capture economic value through inward licensing or spinning out unused ideas (OECD 2008). But not all firms may benefit equally by adopting an open innovation approach. The literature suggests that the effectiveness of open innovation may be contingent on the firm's internal and external context characteristics. Size, strategic orientation and industry are key firm characteristics determining the strength and direction of open innovation activities (Huizingh 2011).

Recent research suggests that open innovation tools (OITs) may facilitate the generation of innovative ideas aimed at sustainability (Arnold and Barth 2012; Carlsson, Hjelm et al. 2015). This may be achieved by engaging stakeholders, such as citizens, in idea competitions. Citizens' integration in the innovation process seems to bring several benefits interesting for the purpose of this research, such as higher levels

of transparency as well as the generation of innovative products/services demanded by society (Arnold and Barth 2012). On the other hand, OITs can contribute to the generation of innovative ideas embedding sustainability issues by creating arenas in which different experts can work collaboratively and generate new actionable knowledge that sparks innovation (Carlsson, Hjelm et al. 2015). Therefore, open innovation seems a promising concept to support the generation of innovative ideas aimed at sustainability, at least, when the search areas are limited to sustainability topics.

2.4.1.3.1 Is open innovation model suitable theoretical framework?

This subsection has reviewed the open innovation model in order to explore whether it could be useful for supporting firms to innovate responsibly. The literature review on this process-based theory provides interesting examples illustrating how open innovation may be useful to generate innovative ideas embedding sustainability issues, at least, if the search areas are directed towards sustainability challenges. Literature shows that open innovation tools enable the active participation of stakeholders in the innovation process. This contributes to the development of new learnings as well as the generation of innovative ideas which embody customer and other stakeholders' values and expectations. These are useful learnings which may be used to facilitate the generation of responsible innovation.

In spite of these interesting insights, open innovation does not seem to provide an explicit and comprehensive framework to support firms in innovating responsibly. The main reason behind this conclusion is that open innovation does not provide any guidance on how to deal with responsibility issues systematically, such as risks related to innovation and values for social, economic and environmental sustainability. Open innovation is an innovation paradigm and strategy that enhances customer and business value, but without considering if the outcomes would cater to the ethical, moral and other values of all stakeholders. It can be argued that open innovation facilitates interaction with and integration of stakeholders in innovation processes, but it does not indicates how the innovation process can be managed in order to ensure that innovation outcomes are social, economic and environmentally sustainable. These are key shortcomings which limits the usefulness of open innovation as the basis of a theoretical framework for this thesis.

In any case, the examples revised provide interesting learnings. For instance, useful for responsible innovation may be the participation and dialogue with stakeholders to facilitate the generation of ideas which embed certain values, such as environmental friendliness. The participation of stakeholders seems to enhance the desirability of outcomes and therefore, their sustainability. So, open innovation can provide useful methods for innovating responsibly.

After reviewing the open innovation model, it seems necessary to look for models of innovation which are more directed to generate innovation outcomes which embed certain values to enhance social, economic and environmental sustainability. In Section 2.4.1.4 it is reviewed an innovation approach revolving around a specific type of innovation which is characterised by embodying sustainability issues: the sustainable innovation approach.

2.4.1.4 Sustainable Innovation approach

Innovation studies literature distinguishes among different types of innovation one which has as main characteristic its capability to support sustainable development (Brundtland 1987). Several concepts can be found in academic literature and business press to denote this particular type of innovation, such as eco-innovation, sustainable product innovation, sustainable innovation or environmentally-oriented innovations, among others (Larson 2000; Rennings 2000; Reid and Miedzinshki 2008; Smith, Voß et al. 2010; Dewulf 2013; Varadarajan 2015). Hereafter, the concept sustainable innovation would be used to refer to innovation towards sustainable development, just for convenience reasons.

Sustainable innovation refers to the firm's implementation of a new product, process or practices with superior environmental performance, in comparison with alternative options (Varadarajan 2015). In sustainable innovation theories and models the environmental dimension of sustainability is core, while the social dimension is far less developed (Adams, Bessant et al. 2012).

In innovation studies literature, two different levels of analysis co-exist with regard to sustainable innovation: a level of analysis at the system level and a second one focused on the firm-level. Hereafter, the literature focused on the system level would not be included in this literature review. The reason is that, as already discussed in the Subsection 2.4.1.2.5, the system perspective sees firm as black boxes (OECD 2008). This limits the usefulness of the system perspective to deal with the research problem and questions defined in this dissertation. Therefore, my next step is to review models of sustainable innovation at the firm-level.

2.4.1.4.1 Sustainable innovation at the firm-level

In the literature, it is possible to find a variety of models that conceptualize the process that firms undergo in order to pass from unsustainable ways of operating to having sustainability more or less embedded in their operations and innovation outcomes. Hereafter, the model suggested by Adams, Bessant et al. (2012) would be outlined. The reason for the choice of that particular model over others is based on the fact that the selected model is built on the insights generated by earlier models suggested in literature. Further, the selected model offers a comprehensive overview of the activities that firms can do to adapt their innovation systems to innovate toward sustainability. So, it seems *a priori* a

valuable model to explore in order to determine whether it can offer a framework to support business organizations to generate and deploy responsible innovation outcomes.

Adams, Bessant et al. (2012)'s model distinguishes three different contexts of sustainable innovation, namely Operational Optimization, Organizational Transformation and Systems Building (see Figure 4). Each context refers to phases in which firms show a distinctive attitude towards sustainability, from less sustainability-oriented to have sustainability fully embedded in firm's values and operations. Thus, firms operating in the Operational Optimization context are characterised by an attitude focused on diminishing the harmful consequences of their activities. On the other extreme, firms in the Systems Building context seek to become increasingly sustainable rather than less unsustainable. These firms operate in coordination with other actors of the socio-technical regime, and conduct and promote changes in their business models as well as in other institutions in order to deliver products and services which provide net economic, social and environmental benefits. The shift between these two extreme requires an adaptation phase, the Organizational Transformation. During this intermediate phase, firms innovate in a more systemic and integrated manner, in comparison with the Operational Optimization phase, and socio-technical factors are increasingly considered in decision making and analysis.

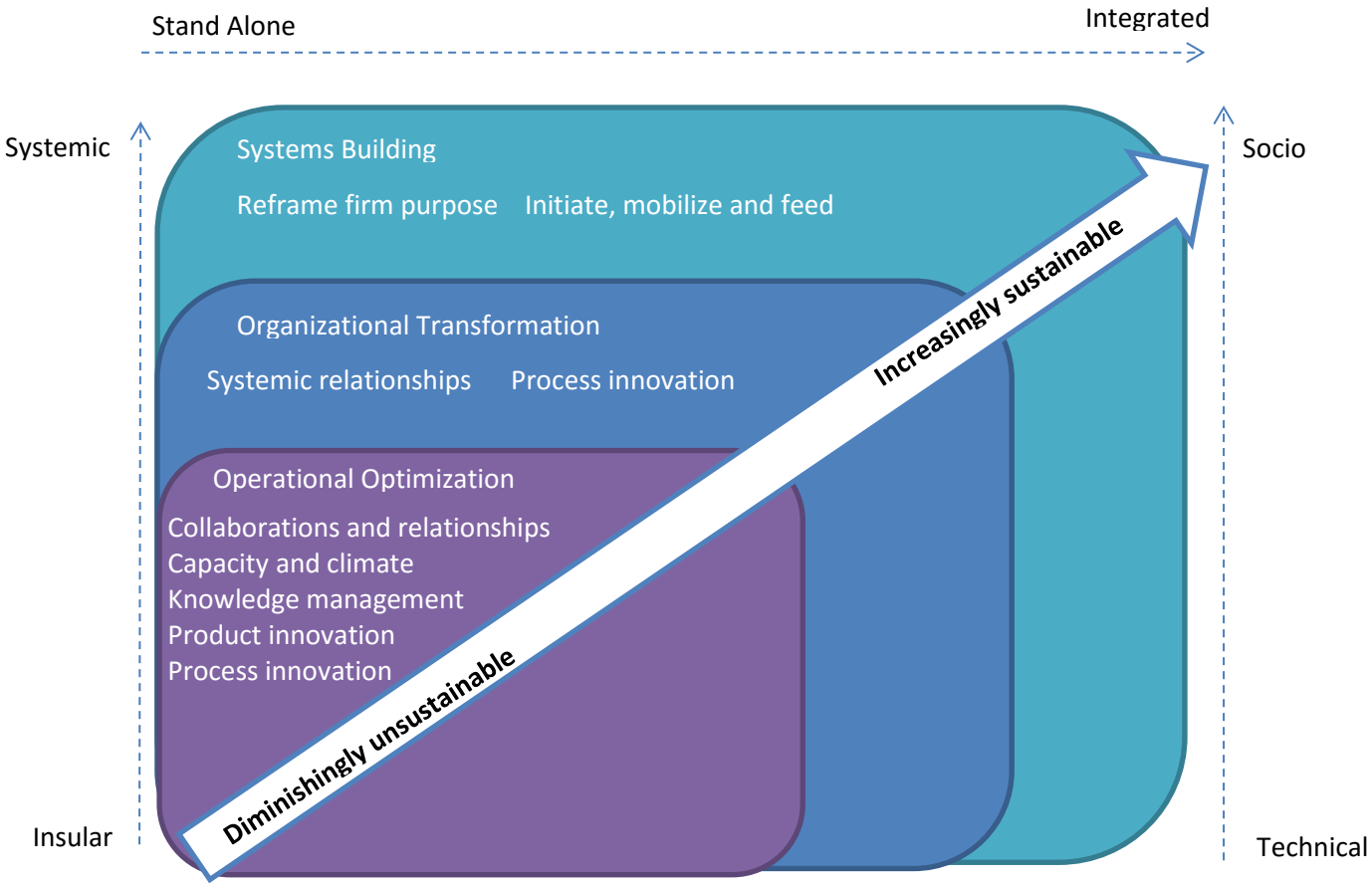

Figure 4. Contexts of sustainable innovation (source: (Adams, Bessant et al. 2012))

For each of the three contexts of sustainable innovation, the authors suggest a list of activities that firms can or should use to embed sustainability issues in innovation. Thus, the model states that to enhance sustainability performance in the Operational Optimization, firms can:

- Create and nurture *collaborations* and *relationships* with stakeholders operating within and outside the firm's boundaries, including regulators, suppliers, knowledge institution, other business units or areas as well as customers;
- Create a *capacity* and *climate* oriented to exploit existing innovation capabilities to facilitate the adoption of incremental innovation as well as to codify, formalize and monitor targets with regard sustainable innovation;
- Adopt strategies such as Design for sustainability, environmental management systems, life cycle analysis methods as well as sustainable supply chain management practices to integrate sustainability issues in the processes of innovation;
- Use design tools to redesign products so their sustainability performance is improved; reduce materials' impacts and products' energy consumption as well as create new products that integrate recovery, reuse, and disposal thinking from the outset of the innovation process;
- Exploit existing *knowledge management* capabilities to support learning about sustainability issues; unlearn existing knowledge that contradicts the firm's sustainability objectives and principles; train staff about sustainability issues and hire professional with sustainability expertise;
- Integrate social, economic and environmental considerations across the firm by issuing guidelines and monitoring compliance.

On the other hand, firms moving beyond the Operational Optimization can develop another set of activities which would enhance further the embedding of environmental, social and economic issues in innovation. In particular, firms that aspire to move to the Organizational Transformation may require developing the following activities:

- Create *systemic relationships*. In this phase, collaborations become increasingly relevant to improve sustainability performance. Firms need to explore collaborations with previously unrelated industries and engage in new innovation platforms which facilitate the development of innovations aimed at the bottom of the pyramid and other vulnerable social groups;
- The innovation *capacity and organizational climate* needs to be reinforced towards sustainability. This may be achieved by ensuring top management's commitment to sustainability, communicating across the firm the values and goals of sustainability, and setting

goals and targets more ambitious than those that can be achieved through operational and eco-efficiencies;

- Create a reward systems and incentives that reinforce sustainability practices and goals;
- At this stage, firms need to rethink their business model and modes of governance to enhance the embedding of sustainability issues as well as to integrate sustainability metrics into financial reporting and adopt transparent sustainability reporting;
- Firms need to search for weak signals and extend their search activities into unfamiliar field;
- Adopt new platforms such as closed-loop manufacturing and cradle-to-cradle innovation;
- Develop new networks into the wider social, economic, legislative systems as well as into supply chains. In this stage, collaboration with external partners is essential;
- Use back-casting approach to foster sustainability innovation and define audacious goals with regard to sustainability;
- Adopt a servitization strategy and expand the search for new product ideas to new areas;
- Learn lessons from other stakeholders and innovation platforms such as frugal innovation.

Finally, Adams, Bessant et al. (2012) suggest some activities for becoming a System Builder, although they recognize that those activities are still under exploration and that there is not empirical evidences of any firm operating at this level. In any case, the model states that firms generating innovations with the highest sustainability performance need to apply a whole-systems focus to influence the redesign of institutions and infrastructures as well as the reconceptualization of the business purpose.

Despite the extensive list of activities and strategies suggested by the above model to innovate towards sustainability, the literature indicates some relevant deficiencies to embed environmental and social issues in innovation. Some researchers have stresses that there is a gap in the sustainable innovation literature on how to integrate sustainability issues from the outset of the innovation process (Dewulf 2013). This is a relevant flaw as innovation management literature stresses that the early stage of the innovation process, known as the Front-End, is essential for the definition and eventual success of the new products and services (Cooper and Kleinschmidt 1993). If sustainability issues are not included from the outset, then to integrate them in later stage can be costly, lead to non-optimum solutions or be just impracticable. On the other hand, many strategies, tools and techniques suggested to deal with sustainability through the innovation process are mainly focused on environmental issues. The social dimension of sustainability is clearly underdeveloped (Adams, Bessant et al. 2012; Dewulf 2013).

2.4.1.4.2 Conclusions on the Sustainable Innovation approach

The literature review provides valuable insights on how to embed sustainability issues in innovation outcomes and processes. This provides a framework to generate and develop innovations which embed environmental issues and, to a lesser extent, social issues. The model reviewed stresses the necessity of collaboration with different stakeholders to embed in innovation sustainability issues. Further, it emphasizes the use of different tools, strategies, methods and management systems to facilitate the design and development of innovation outcomes with a better environmental performance, in comparison with alternative options. Overall, the reviewed model synthesizes the accumulated learnings to generate sustainable innovation. No doubt that all these learnings can and should be considered to innovate responsibly.

But the revised model presents some deficiencies that may limit its attractiveness for becoming a suitable framework, by itself, to help firms in their effort to generate responsible innovation. These limitations are, on the one hand, the weak consideration of ethics and social issues and, on the other hand, the insufficient integration of sustainability issues from the outset of the innovation process. The first of these limitations is especially relevant for the purposes of this research. As the literature shows, certain controversial innovation outcomes, such as genetically-modified crops, were strongly contested by certain societal groups because ethics, religious, moral and other issues were not properly considered from the outset (Hall and Vredenburg 2003). So, embedding environmental issues in innovation may be a necessary condition to generate innovation outcomes responsibly, but insufficient if other issues affecting their economic and social acceptability or desirability are neglected. Therefore, the above model does not provide a comprehensive framework to support firms in the efforts to generate and deploy innovation outcomes which society would consider as ethical, desirable and sustainable.

Models and approaches of innovation revised so far do neither provide a comprehensive and explicit framework to deal with responsibility issues nor to support firms in their efforts to generate innovation outcomes which embed certain values for social, economic and environmental sustainability. Moreover, the reviewed approaches do not provide enough guidance on how firms may develop their innovation processes to produce responsible innovation. Therefore, there is necessary to explore alternative models and approaches to address the research questions posed in this Thesis. In the next section, an emerging and promising approach of innovation, called Responsible Innovation, is reviewed.

2.4.2 The Responsible Innovation approach

In innovation studies it is increasingly acknowledge that innovation produces positive impacts as well as new risks and social concerns. Aware of this, several scholars have called for a new and more appropriate approach of innovation. This should help in assessing the ethical, environmental, legal, and social implications of research and innovation as early as possible in order to minimise their risks and enhance their embedding in society (e.g. (Hellström 2003; Guston 2004)). The Responsible Innovation (RI) approach is an attempt to address the shortcomings of existing innovation approaches to address the sustainability of innovation. To do this, it is stressed the need of embedding and/or taking care of certain values in new research, development and innovation. A comprehensive review of this new approach is presented in this section. Further, this section would also provide the justification for adopting RI as the basis of a theoretical framework for helping firm to innovate more responsibly (Section 2.4.2.4). In Section 2.4.2.5, conclusions on the review of Responsible Innovation would be presented.

2.4.2.1 Premises of the Responsible Innovation approach

The RI approach emerged from the evidence that existing legal and regulatory mechanisms are ineffective to prevent undesirable and unforeseen impacts resulting from new research and innovation. Owen, Stilgoe et al. (2013) argue that this ineffectiveness is based on the fact that, currently, responsibility is judged retrospectively, once the innovation outcomes have been commercialized and their undesirable effects are evident and difficult to revert due to 'lock-in' and path dependence effects. Therefore, they suggest the necessity of a new approach to innovation which allows the control, modulation and shaping of innovation trajectories based on societal values and considerations. In this sense, RI is related to other concepts such as Constructive Technology Assessment (Schot 1992; Schot 1997), Real Time Technology Assessment (Guston and Sarewitz 2002) Midstream modulation (Fisher, Mahajan et al. 2006) and Anticipatory Governance (Barben, Fisher et al. 2008)

According to Owen, Macnaghten et al. (2012), RI is an innovation approach that not only seeks to avoid the potential risks of scientific and technological development. Owen, Macnaghten et al. (2012) argues that a distinctive feature of RI is that it aims to facilitate both the definition of the direction and the modulation of the trajectory of innovation towards socially desirable or 'right' impacts. To achieve this, RI explores how societal actors can define in an inclusive, ethical and equitable manner what innovation should do or achieve and what innovation should not do, in order to enhance the quality of life as well as the safe embedding of innovation in society (Owen, Stilgoe et al. 2013). Further, RI reflects on which societal values or 'right' impacts innovation may be anchored to be considered as responsible. According to von Schomberg (2013), in the European context the 'right' impacts that can guide innovation could be

those that have been enshrined in the European Treaty, such as *sustainable development* or *quality of life*, as they have been legitimated through a democratic process. On the other hand, Owen, Stilgoe et al. (2013) argue that RI cannot be decoupled from its context as what is desirable or acceptable would depend on it. Finally, the RI approach explores how to deal with conflicts and dilemmas among (contradictory) values in order to generate innovation outcomes which are socially desirable or at least acceptable (Owen, Stilgoe et al. 2013; Ravesteijn, He et al. 2014).

According to Owen, Stilgoe et al. (2013), RI is based in a new, prospective perspective of responsibility. This prospective responsibility is conceptualized through two concepts: *care* and *responsiveness*. This has relevant implications: 1) RI allows for reflection on purposes (i.e. is ethical and value-based); 2) it accommodates uncertainty, which is inherent to the innovation enterprise, and 3) responsibility is not embedded in innovation through specific rules, but through general guidelines.

Core to RI is the integration of stakeholders early in the innovation process. This is proposed as a mechanism that may help govern the innovation impacts at the early stages of technology development and enhance thus the embedding of innovation outcomes in society (von Schomberg 2013).

2.4.2.2 A brief overview of areas in which Responsible Innovation has been explored

Early references to the term 'responsible innovation' go back to the beginning of the Twenty-first century, when Hellström (2003) and Guston (2004) used it to call for a new way of managing research and innovation. In particular, Hellström (2003) advocates that there is a need for creating new ways of managing innovation so that environmental, social and economic risks associated with complex and pervasive technologies can be better assessed and managed. Hellström (2003) suggests the creation of "arenas of trustworthiness" in which the relevant actors involved in, and affected by critical innovation processes can work together for effectively assessing and managing risk generating practices related to a technological system. In his own words: "the ultimate goal of maintaining such arenas would be, no simply risk reduction, but a proactive form of responsible innovation". Ultimately, Hellström (2003)'s proposal is the creation of a preventive foresight and governance system which involves a network of actors for the assessment of "unplanned or unanticipated consequences" of systemic technologies. It is at this point in which the early conceptualizations of RI is linked to other existing approaches of technology assessment, such as Constructive Technology Assessment (CTA) (Schot 1992; Schot 1997) and Real-Time Technology Assessment (RTTA) (Guston and Sarewitz 2002).

On the other hand, Guston (2004) further contributes to the concept of responsible innovation, but in this case, with regard to the knowledge-based innovation resulting from university research. In particular, Guston (2004) argues that "new ways must be found to manage the ethical, legal, and social

implications of research that aspires to help people pursue more uplifting lives in more just societies". For creating and performing this new ways of managing the ethical, legal, and social implications of research, Guston (2004) suggests the creation of centres for responsible innovation (CRIs). These would support other research groups and departments to integrate ethics and responsibilities issues into their academic activities. Further, it is suggested that CRIs could contribute to research the ethical, legal, and social implications of research. Moreover, Guston (2004) sees CRIs as platforms, or hubs, in which different actors, including researchers, businesses, and lay people, are engaged in order to exchange information and points of view about innovation and its potential implications. Again, the application of RI is thus associated, or derived from, technology assessment practices as well as other innovation and research approaches in which participatory and deliberative methods are used. All in all, it is possible to conclude that early conceptualizations of the RI point to: (1) a way of managing innovation activities so that its outcomes integrate socio-technical considerations for a safe embedding in society; and (2) the interactions of multiple actors who bring their knowledge and perspectives in order to understand the intended and unintended consequences and modulate the trajectory of development through incorporating ethical, legal, social, as well as environmental and economic issues into it.

Besides the above references, the RI[3] concept has evolved and been developed around different technologies and industries. The nanotechnologies community has been a fertile ground for RI (some references of an extensive list are the following: (EC 2008), (Society, Investment et al. 2008), (Widmer, Meili et al. 2010), (Mantovani, Porcari et al. 2010), (Selin and Boradkar 2010), (Owen 2010), (Roco, Harthorn et al. 2011) and (Pandza and Ellwood 2013)). Concerns about potential negative impacts of nanotechnologies and nanomaterials (N&N) on socio-ecological systems have stimulated the development of several codes of conduct and practice (Mantovani, Porcari et al. 2010). These codes suggest a set of principles and guidelines for responsible research and development of N&N. For instance, the Code of Conduct proposed by EC (2008) suggests the following principles for responsible research on N&N:

- **Meaning:** N&N research should respect fundamental rights and be conducted in the interest of the well-being of individuals and society in their design, implementation, dissemination and use.
- **Sustainability:** N&N research activities should be safe, ethical and contribute to sustainable development.

[3] It is important to highlight that RI has been named differently in certain technological fields. Thus, Responsible development is the term more used on studies related to nanotechnologies, while 'Responsible Research and Innovation (RRI)' is more frequently used on policy making and research environments.

- **Precaution:** N&N research activities should be conducted in accordance with the precautionary principle, anticipating potential environmental, health and safety impacts of N&N outcomes and taking due precautions, proportional to the level of protection, while encouraging progress for the benefit of society and the environment.
- **Inclusiveness:** Governance of N&N research activities should be guided by the principles of openness to all stakeholders, transparency and respect for the legitimate right of access to information.
- **Innovation:** Governance of N&N research activities should encourage maximum creativity, flexibility and planning ability for innovation and growth.
- **Accountability:** Researchers and research organizations should remain accountable for the social, environmental and human health impacts that their N&N research may impose on present and future generations.

Similarly, the Responsible NanoCode proposes the following set of guidelines for the responsible development and commercialization of N&N (Society, Investment et al. 2008):

- **Board accountability:** Accountability ought to reside with the board or is delegated to an appropriate senior executive committee
- **Stakeholder involvement**
- Ensuring high **standards of occupational health and safety** for staff handling nano-enabled products
- Wider **social, ethical, environmental and health impacts** assessments
- **Engaging with business partners** to encourage and stimulate the adoption of the Code
- **Transparency and disclosure** with regard to how the Code is implemented

Other technologies in which RI has been discussed are the information and communication technologies (ICTs) (EC 2011; Venier 2011; Stahl, Eden et al. 2014). In this area, the RI discourse has mainly focussed on the ethical governance of ICTs, and especially on how to deal with certain values, such as privacy, in technology development. It is in the ICTs area where it is possible to find one of the first proposal of what could be a general framework for RI (EC 2011). Table 3 below summarizes the main elements of this framework, which will be explained in more detail in next Section 2.4.2.3.3[4].

[4] The methods for RI suggested in EV (2011) are the basis of the framework developed by von Schomberg (2013)

Table 3. Overview on features of responsible research and innovation

FEATURES OF RESPONSIBLE RESEARCH AND INNOVATION	
PRODUCT DIMENSION: ADDRESSING NORMATIVE ANCHOR POINTS	**PROCESS DIMENSION: DELIBERATIVE DEMOCRACY**
Institutionalisation of Technology Assessment and Foresight	Use of Code of Conducts
Application of the precautionary principle; ongoing risk assessment; ongoing monitoring	Ensuring market accountability: Use of Standards, Certification schemes, Labels
Use of demonstration projects: from risk to innovation governance	Ethics as a design principle for technology
	Normative models for governance
	Ongoing public debate: moderating 'Policy Pull and Technology Push'

Source: (EC 2011)

RI is also an emerging field in the financial services industry as a response to the financial crisis of the late 2000s (Armstrong, Cornut et al. 2012; Muniesa and Lacoste 2012; Muniesa and Lenglet 2013).

Other areas in which the approach of RI has been explored is in developing countries and, in particular, with regard to the deployment of energy networks (Singh 2012), small producers' cluster (Voeten 2012) and solar technologies (Setiawan and Singh 2015). On the other hand, Ravesteijn, He et al. (2014) has explored the concept of RI with regard to the development of a large infrastructure project in China. In his publication, Ravesteijn, He et al. (2014) suggest the following five-step procedure for dealing with value conflicts with regard to innovation:

- Identify stakeholders
- Assess impacts of project to stakeholders
- Identify diverse values of stakeholders
- Analyse value conflicts among stakeholders
- Establish a governance mechanisms to resolve value conflicts

2.4.2.3 Frameworks for Responsible Innovation

In the previous section, it has been outlined different codes of conducts, procedures and methods suggested in literature for fostering RI. This section will focus on general frameworks for Responsible Innovation suggested by different scholars (Singh 2012; Owen, Stilgoe et al. 2013; von Schomberg 2013). These are not associated with any particular technology, but they have been proposed to help researchers and firms operating in different sectors and working with any technology. Hereafter, these frameworks are reviewed.

2.4.2.3.1 Singh and Otto's framework for Responsible Innovation

Singh (2012) suggests a framework for RI consisting of the following main conceptual components:

1) Being caring and ensuring care for certain values
2) Ensuring the goals of social, environmental and economic sustainability
3) Five dimensions of responsible innovation

1) **Being caring and ensuring care for certain values.** Singh (2012) indicate that RI requires business organizations' members and entrepreneurs to be sensitive to, and exhibit concern and empathy towards certain values. Further, they stress that to innovate responsibly firms need to assume responsibility for those values. This means that firms ought to ensure that certain values are properly embedded in innovation. Certain values involve both universal as well as culturally specific values. Further, Singh (2012) emphasize the need to embed in innovation the prevailing values of the context in which innovation will be deployed. This, they suggest, facilitates the adaption of innovation to the context in which it will be deployed, enhancing the adoption of innovation by culturally different groups as well as avoiding negative impacts.
2) **Ensuring the goals of social, environmental, and economic sustainability as a goal.** Singh (2012)'s suggest 'social, economic and environmental sustainability' as the principal goals, or 'right' impacts for guiding firms to innovate responsibly. Sustainability here means that by deploying innovation outcomes the needs of current generations are met without compromising the ability of future generations to meet their own needs. Sustainability is considered in its three components or aspects: social, environmental and economic. According to Singh (2012), social sustainability means that benefits resulting from innovation are shared among all members of society affected by innovation. Further, social sustainability means that innovation outcomes do not affect negatively the culture, way of living and social harmony of individuals and societal groups. On the other hand, environmental sustainability means that innovation outcomes should neither adversely affect to ecological systems nor human health. Finally, economic sustainability indicates that innovation outcomes should be affordable, accessible and durable for users and customers.
3) **Dimensions of responsible innovation.** Singh (2012) suggest five mechanisms or dimensions for RI: the Anticipation, Reflexivity, Deliberation, Responsiveness and Participation dimensions. Hereafter, each dimension is outlined:
    - The Anticipatory dimension indicates that business organizations need to be future oriented and apply foresight throughout the innovation enterprise. Knowledge about

the future implications of innovation, both positive and negative, is generated to support decision making processes with regard to different aspects of innovation.

- On the other hand, the Reflexivity dimension involves that business organizations innovate in a reflexive manner, i.e. the innovation process embeds mechanisms that ensure that those involved reflect on different expectations, desirability, needs, issues and risks, to adjust, if necessary, the developing trajectory of innovation to ensure that certain values are embodied in innovation outcomes.
- The Deliberation dimension entails that innovation related issues are carefully explored and discussed from the multiple perspectives involved in order to make innovation outcomes acceptable and workable.
- The Responsiveness dimension refers that innovation processes are able to respond to, and address stakeholders' needs, requirements, views, issues and values.
- The Participatory dimension indicates that the innovation process ensures the participation of stakeholders in order to address and accommodate the different views and interests revolving around innovation.

2.4.2.3.2 Owen, Stilgoe et al.'s framwork for Responsible Innovation

Owen, Stilgoe et al. (2013) has suggested a four-dimension framework for fostering RI. According to Owen, Stilgoe et al. (2013), innovating responsibly entails a collective and continuous commitment to be:

1) Anticipatory: It involves describing and analysing the intended and unintended impacts resulting from research and innovation. It stimulates thinking about 'what if…' and 'what else might it do' in order to surface issues and explore possible impacts and implications that may otherwise remain little explored.

2) Reflective: It encompasses reflections on issues such as underlying purposes, motivations, and potential impacts of research and innovation, but also about what is known and what is not known. Reflection is also proposed to explore and question uncertainties, risks, areas of ignorance as well as assumptions and dilemmas.

3) Deliberative: This dimension stimulates broad and collective deliberation about the visions, purposes, questions and dilemmas associated with research and innovation. This deliberation is articulated through dialogues, engagement and debates with public and diverse stakeholders. Deliberation, it is argued, facilitates incorporating a broad range of perspectives in the process to frame issues as well as to anticipate areas of potential contestation.

4) Responsive: It refers to set the direction and influence the developing trajectory and pace of innovation according to the outcomes of the reflexive process. Responsiveness, it is suggested, is achieved by articulating an iterative, inclusive and open process of adaptive learning.

The above framework has been later reviewed and extended by some of its proponents (Stilgoe, Owen et al. 2013). In the second version, the deliberation dimension is replaced by the Inclusion dimension. Further, it encompasses certain techniques and approaches that can be used for facilitating the deployment of the above dimensions in research contexts.

Table 4. Framework for responsible innovation

Dimension	Indicative techniques and approaches
Anticipation	Foresight Technology Assessment Horizon scanning Scenarios Vision assessment Socio-literary techniques
Reflexivity	Multidisciplinary collaboration and training Embedded social scientists and ethicists in laboratories Ethical technology assessment Codes of conduct Moratoriums
Inclusion	Consensus conferences Citizen's juries and panels Focus group Science shops Deliberative mapping Deliberative polling Lay membership of expert bodies User-centred design Open innovation
Responsiveness	Constitution of grand challenges and thematic research programmes Regulation Standards Open access and other mechanisms of transparency Niche management Value-sensitive design Moratoriums Stage-gates Alternative intellectual property regimes

Source: Adapted from (Stilgoe, Owen et al. 2013)

2.4.2.3.3 Von Schomberg's framework for Responsible Innovation

The framework for RI suggested by von Schomberg (2013) distinguished two interrelated dimensions:

1) Product dimension. von Schomberg (2013) defines responsible products as those that ensure a high level of protection to the environment and human health, are sustainable and socially desirable. In this case, social desirability is associated with normative anchor points included in the Treaty on the European Union (EU), such as "Quality of life" and "Equality among men and women".

2) Process dimension. von Schomberg (2013) relates a responsible innovation process with an innovation process that is managed in a responsive, adaptive and integrated manner, in which different stakeholders are engaged. He suggests that in responsible innovation processes, innovators become responsive to societal needs and, at the same time, societal actors become co-responsible for the innovation process by defining societally-desirable products. Further, he suggests five mechanisms to implement responsible innovation processes:

- **Use of technology assessment and technology foresight**: These methods are proposed as a means to anticipate the positive and negative impacts of innovation, as well as to define the desirable impacts of innovation activities on society. On the other hand, von Schomberg (2013) advocates that the setting of research priorities and their anticipated impacts need to be done through a societal review process. Thus, research ought to be reviewed from a scientific point of view as well as from the (potential) societal impacts associated with. On the other hand, technology assessment methods are recommended as a means to enhance the social desirability of innovation outcomes by addressing societal values early in innovation development.
- **Application of precautionary principle:** von Schomberg (2013) argues that the application of the precautionary principle is a useful mechanism and legal requirement within the EU to avoid negative impacts resulting from research and innovation.
- **Normative/ethical principles to design technology:** It is suggested the incorporation of ethical principles in the design process of technology as a means to increase acceptability of technological innovations.
- **Innovation governance:** von Schomberg (2013) stresses that policy instruments will be insuficient to ensure a safe deployment of the increasing number of products and processes coming on to the market. Therefore, he suggests the adoption of standards and a self-regulating mechanisms as a means to strenght the governance of innovation.

- **Stakeholder involvement and public engagement**: It is suggested the involvement of stakeholders in the definition of an implementation plan for the responsible development of a particular product within a specific research/innovation field. von Schomberg (2013) emphasizes that the involved actors have to take a position on all aspects of the innovation process, avoiding to focus only on particular aspects as risk associated with innovation. On the other hand, it is recommended to provide continuous feedback from the outcomes of technology assessment and foresight to policy makers. It is also proposed the creation of models of responsible innovation governance in which all stakeholders have a responsibility for the process and outcomes. This is expected to enhance the responsiveness of involved actors, including innovative companies as well as NGOs and other stakeholders. Finally, von Schomberg (2013) argues that ongoing public debate and monitoring of public opinion may increase the legitimacy of research funding and particular scientific and technological advances.

2.4.2.4 Justification for the selection of a Theoretical Framework

The review of literature on RI approach indicates that RI is an approach that aims at enhancing the embedding of innovation outcomes in society by addressing aspect of responsibility in the innovation process. This is clearly in line and coherent with the research objective and questions of this dissertation. Further, RI seems to meet satisfactorily all criteria defined in Section 2.2.3. Therefore, RI is considered as the most suitable approach to provide a theoretical framework for this Thesis.

The review also shows that different codes of conducts and practices have been suggested to support the responsible research and development of certain controversial technologies. These codes are based on general principles such as sustainability, stakeholder's dialogue and precaution. They also suggest certain mechanisms for embedding responsibility issues through the innovation process (e.g. stakeholder involvement, assessment risks, etc.). On the other hand, three different frameworks for RI have been found in literature and reviewed. So, which mechanisms can be used for fostering RI at the firm-level? Which of the different frameworks could be the most suitable for this Thesis?

The use of codes of conducts, risk management, public dialogue and other mechanisms suggested for the responsible development of specific technologies may be useful for governing certain areas of the innovation process but they do not seem to offer an overarching, coherent framework unless it is not considered how they are aligned with one another (Stilgoe, Owen et al. 2013). Further, these mechanisms can be considered as second-order mechanisms. They codify in a structured manner other more general mechanisms (e.g. anticipation, reflexivity, etc.) that have been proposed for embedding responsibility issues through the innovation process. So, in spite of the fact that codes of conducts,

technology assessment, standards and other mechanisms suggested by von Schomberg (2013) are useful for helping firms to innovate more responsibly, it is considered that the frameworks of Singh (2012) and Owen, Stilgoe et al. (2013) offer *a priori* a most suitable basis for a framework for this thesis.

The frameworks for RI suggested by Singh (2012) and Owen, Stilgoe et al. (2013) present some differences which should be analysed:

- The two frameworks differ on the mechanisms to be deployed for responsible innovation. Thus, Singh (2012) suggest participatory and deliberative mechanisms in order to foster RI, while Owen, Stilgoe et al. (2013) propose to engage with stakeholder through deliberations (or inclusion in the version suggested by (Stilgoe, Owen et al. 2013)). Is this difference relevant in order to innovate responsibly? The literature review on Open and Sustainable Innovation has showed that stakeholder participation is a useful mechanism to facilitate the generation of ideas and products which aims at sustainability. Therefore, not including a participatory dimension may be a key limitation of the frameworks suggested by Owen, Stilgoe et al. (2013).
- The framework suggested by Owen, Stilgoe et al. (2013) has been created for embedding responsibility issues in the early stages of the innovation process (the framework was created in part for fostering RI with regard research project in the controversial area of geoengineering (Stilgoe, Owen et al. 2013)). Thus, the methods that have been proposed for deploying the different dimensions may not be the most adequate for helping firms to consider responsibility issues throughout the innovation process, from ideation to commercialization. On the other hand, the framework suggested by Singh (2012) is more general and not limited in scope, although not methods have been suggested for implementing the dimensions.
- The framework proposed by Singh (2012) suggests that RI implies that firms need to ensure care for universal and culturally specific values for social, economic and environmental sustainability. On the other hand, Owen, Stilgoe et al. (2013) and Stilgoe, Owen et al. (2013) suggest that RI is a collective commitment of care of the future' or 'means taking care of the future'. These two general principles are more ambiguous and may offer less guidance in order to implement RI at the firm-level than the one suggested by Singh (2012).

Based on the above assessment, the framework suggested by Singh (2012) seems the most suitable for being used at different contexts and industries, and therefore it will be adopted as a basis to address the research problem poses in this Thesis. Having said that, Singh (2012)'s framework shows some limitations which calls for further development. First, it does not state why every dimension is needed for innovating responsibly. Second, it does not indicate how every dimension may support firms at different stages of the innovation process. Third, it does not indicate methods which can be useful to

deploy the different dimensions. Hence, section 2.4.3 would be devoted to evolve the framework suggested by Singh (2012) in order to build a comprehensive theoretical framework for this dissertation.

2.4.2.5 Conclusions

This section has reviewed an emerging and developing approach of innovation called Responsible Innovation. Core to RI is to research and explain how innovation can be created so that it is socially desirable or at least socially acceptable. For that, RI suggests a new and prospective conceptualization of responsibility based on concepts such as care, responsiveness, deliberation and anticipation. The RI approach reflects on the values in which innovation should be anchored to be considered as responsible. Further, it explores how stakeholders can define in an inclusive, ethical and equitable manner what innovation should do and should not do. Moreover, RI explores how to deal with value conflicts that may appear throughout the innovation process in order to enhance the embedding of innovation outcomes in society. Based on this features of the RI, it has been considered the most suitable approach to address the research problem on understanding how to support firms to innovate more responsibly.

The literature review also showed that several frameworks have been proposed for RI. After assessing three of these frameworks, it was concluded that the one suggested by Singh (2012) is the most suitable to answer the following research question: *How could responsibility issues be embedded through innovation processes to facilitate the generation of responsible innovation according to existing theories and models of innovation?* In any case, the framework suggested by Singh (2012) is not comprehensive enough as it does not provide an overview of the methods that firms may use to create responsible innovation. To overcome this gap, it would be required understanding how the different dimensions can be used in the innovation process to support responsible innovation and, based on that understanding, to identify potential methods which firms can deploy to make the innovation process follow each dimension. This will be the purpose of the next section.

2.4.3 Evolving the Theoretical Framework for Responsible Innovation

2.4.3.1 Introduction

The RI approaches proposed by Singh (2012) does not provide a comprehensive lists of methods and tools which could be used by innovators to deploy the mechanisms for Responsible Innovation. This limits our ability to understand how RI can be implemented by firms.

In order to identify potential methods that can be used for RI, first it is required to understand why and how each dimension is necessary for RI. Once this is clarified, it would be possible to identify certain methods that can be used to implement the dimensions for RI through the different of the innovation

process, from ideation to commercialization. But, which are these activities? In innovation studies, several authors have indicated key activities that firms perform through the innovation process to bring in new or modified products[5] to the market (e.g. (Cooper and Kleinschmidt 1986; Cooper 1988b; Koen, Ajamian et al. 2002)). Based on the activities identified by Cooper and Kleinschmidt (1986) and Koen, Ajamian et al. (2002), a three-stage model of the innovation is adopted to facilitate the identification of methods that could support RI. According to this model (see Figure 5), the innovation process consists of the Front-End, the Development and Commercialization stages. In the Front-End, firms may develop the following key activities: opportunity identification and analysis, idea generation and enrichment, idea selection and concept definition[6] (Koen, Ajamian et al. 2002). On the other hand, the Development stage may encompass activities such as: product development, in-house product testing, customer tests of products and test market/trial sell. Finally, the Commercialization stage may involve activities such as production start-up and market launch (Cooper and Kleinschmidt 1986).

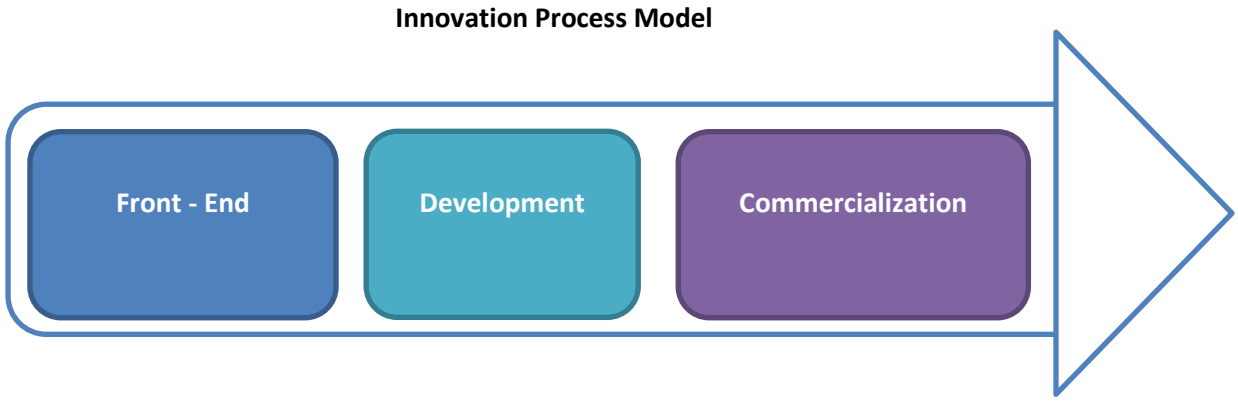

Figure 5. Generic model of the innovation process that it is used to support the identification of methods for responsible innovation (Source: Adapted from Cooper and Kleinschmidt (1986) and Koen, Ajamian et al. (2002))

Next, the five dimensions of RI suggested by Singh (2012) would be further developed as a necessary step to facilitate the identification of methods for RI. The development consists of a theoretical explanation of why each dimension is necessary for RI and how each dimension may support different activities conducted in the innovation process (Section 2.4.3.2). Based on that, certain methods that could help make the innovation process follow each dimension would be suggested in Section.

[5] The word 'product' will be used as a short version of the concept innovation outcome.
[6] The activities perform in each stage may depend on the type of innovation outcomes that the firm is pursuing. Thus, activities may vary depending on whether the firm attempts to create a product, process, service or a new way of organizing.

2.4.3.2 Theoretical explanation of the five dimensions of RI

2.4.3.2.1 The Anticipation dimension

The Anticipation dimension can support firms to innovate responsible in several ways. First and most important for RI, it may help in embedding responsibilities in the innovation process in a forward-looking manner. This is essential to facilitate the generation of products embedding certain values for social, economic and environmental sustainability. Second, it may help firms to generate knowledge about the future developments and to use this knowledge to support the generation of new or improved products which are better aligned to the values that customers and society may held in future. Next, these two arguments are further developed.

As discussed in Section 2.4.2.1 and in line with Owen, Stilgoe et al. (2013), responsible innovation entails the embedding of responsibilities in the innovation process in a forward-looking manner. This embedding can be done through the application of the duty of (reasonable) care. This means that firms would only be judged by society as responsible if they take measures against foreseeable negative effects resulting from innovation outcomes, and possibly also look after as yet unforeseen ones (Doorn 2011). Hence, firms that attempt to generate products which are social, economic and environmentally sustainable ought to anticipate, and manage before commercialization, the intended and unintended effects of products in order to avoid unacceptable harms upon people, the environment and/or socio-economic systems. So, the Anticipatory dimension would entail all activities performed by firms to identify and address before commercialization those potential impacts which could threaten certain values necessary for ensuring the social, economic and environmental sustainability of innovation outcomes.

On the other hand, engaging in anticipatory activities can also support firms to innovate responsibly by providing key knowledge about the future environment. Thus, firms can engage in anticipatory or foresight activities in order to generate knowledge about future customer needs as well as future political, environmental, technological, social, economic and other developments which may shape societal values, and therefore, the market and social desirability of prospective products (Ruff 2006). The generated knowledge can then be used 1) for orienting the innovation process towards more socially desirable avenues; 2) for supporting the generation of innovative ideas that fit with future customer needs and social values and/or 3) for challenging basic assumptions of developing ideas and projects against the prospective environment in which innovation would be embedded (Rohrbeck and Gemünden 2011). Therefore, the Anticipatory dimension would support RI by generating knowledge about the future which can be used to identify and embed in innovation those values that are expected to determine the social, economic and environmental sustainability.

2.4.3.2.2 **The Participation dimension**

Responsible innovation is contingent on the participation of different stakeholders in the innovation process. Before detailing the reasons underpinning this statement, the concept of stakeholders deserves some clarification. There are several definitions of the concept of stakeholder, being the most well-known the one suggested by Freeman (1984). Freeman (1984) defined stakeholder as 'any group or individual who is affected by or can be affect the achievement of an organization's objectives'. In the case of RI, I believe a more general definition of the concept is needed to expand the scope of stakeholder to anyone that could be affected and/or concerned with firm's innovation activities and her outcomes. Therefore, in this dissertation a stakeholders would be understood as 'an individual, organization, group of individuals, or group of organizations that can affect or be affected by a certain topic (theme, decision, or achievement of an objective) (Quist 2007).

The participation of stakeholders in the innovation process can contribute to RI by increasing the odds of identifying and embedding in innovation those values necessary for social, economic and environmental sustainability. This identification and embedding of values for sustainability can be done at several key activities of the innovation process. For instance, the participation of stakeholders in activities aimed at the identification and analysis of opportunities for innovation can help firms to identify those directions or areas which are socially desirable. Moreover, the active participation of stakeholders in idea generation can help firms to gather ideas which already embed certain values for social, economic or environmental sustainability (Arnold and Barth 2012; Carlsson, Hjelm et al. 2015). On the other hand, the participation in the innovation process of experts from different fields can help firm in the early identification of potential risks resulting from innovative ideas and products (Wardak, Gorman et al. 2008). This enables, as discussed in the Anticipatory dimension, to anticipate how innovation can threaten certain values necessary for sustainability, and to act so that these values are properly taken care. Similarly, the engagement with stakeholders, such as Non-Profit Organization (NPOs), in the screening and assessment of innovative ideas and products may facilitate that certain values are given due regard (Antal and Sobczak 2005; Van Huijstee and Glasbergen 2008). Further, the engagement with stakeholders, such as local communities, the affected and concerned or NPOs may facilitate the identification and consideration of stakeholders' values. The embedding of those values in innovation outcomes it increases the legitimacy of innovation outcomes (Yaziji 2004) and, therefore, their social desirability or acceptability. Overall, the engagement of stakeholders through the innovation

process may increase the accountability of the involved actors[7], both innovators and stakeholders (Quist 2007).

Responsible innovation would probably require the participation of customers and other affected and/or concerned stakeholders. The literature suggests that the participation of customers at the early stages of the innovation process is a useful mechanism for a better understanding of their values and needs as well as for developing ideas and concepts which embed those values (Prahalad and Ramaswamy 2000; Kristensson, Gustafsson et al. 2004; Prahalad and Ramaswamy 2004; Ramaswamy 2009). Furthermore, the active engagement of customers in other stages of innovation process enables testing and assessing whether concepts and prospective products properly embed customer values (e.g. (Buur and Bagger 1999)). This provide firms useful insights which can be used to make adjustments on the value proposition in order to enhance the marketability, acceptability and sustainability of innovation outcomes.

The early involvement in the innovation process of other stakeholders beyond customers can support RI by helping firms to anticipate potential areas of societal contestation. Thus, the participation of those affected and/or concerns with innovation through the innovation process can provide key insights that it can be used to change the trajectories of innovation in order to enhance its social, economic and environmental sustainability (Hart and Sharma 2004). Last but not least, the participation of stakeholders through the innovation process can help firms to gather key resources (ideas, knowledge, technologies, etc.) which may be essential for tackling, through innovation, complex societal or environmental problems (Hemmati 2002; Hart and Sharma 2004; Holmes and Smart 2009)

2.4.3.2.3 **The Deliberation dimension**

Firms striving to innovate responsibly are faced with what can be considered as a complex and ambiguous problem-solving situation. Complexity in RI derives from the higher number of stakeholders that need to be taken into account, in comparison with market-driven innovation, to create innovation outcomes which contributes to social, economic and environmental sustainability (Hall and Vredenburg 2003). On the other hand, ambiguity and uncertainty are inherent in RI, as in innovation in general, because of the varied and even contradictory interests, values and requirements that have to be handled, and somehow brought together, in order to generate workable, ethical and sustainable outcomes. As a result, those attempting to innovate responsibly are faced with the challenge of making

[7] The legitimacy of outcomes is increased as more stakeholders have been involved in the process. On the other hand, accountability is enhanced as stakeholders involved become co-responsible for the decision and the consequent activities and action plans.

decisions about innovation in a context in which multiple perspectives must be observed in order to come to optimal solutions which are acceptable by all involved stakeholders.

In this complex decision-making context, those involved in the innovation process can use *deliberations* as an effective and useful mechanism to reduce the equivocality of complex and problematic issues and decisions (Pava 1983). Deliberations refer to a dialogue and argumentation process that allows the parties involved to exchange viewpoints and gain in-depth understanding of their own and each other's positions and underlying assumptions (van de Kerkhof and Wieczorek 2005; Roelofsen, Boon et al. 2011) Through deliberation, innovators can engage with themselves and/or other stakeholders to acquire, share and interpret key information and make decisions about innovation related issues, which could not be effectively made by any single person (Purser, Pasmore et al. 1992). Thus, deliberations may be a useful mechanism to enhance decision-making processes on how to deal with the necessary and sometimes conflicting values related to the economic, social and environmental sustainability of innovation.

On the other hand, stakeholder deliberations[8] can be a helpful mechanism for RI for two additional reasons. First, deliberation with stakeholders can help firms to develop interactive and relational learning processes that facilitate the identification and understanding of stakeholder values and concerns. These insights, if properly considered through the innovation process, increase the odds of generating outcomes whose feature embody the necessary values for social, economic and/or environmental sustainability (Van Huijstee and Glasbergen 2008; Ravesteijn, He et al. 2014). Second, deliberations with stakeholders can also be an effective mechanism to produce a shared understanding of the problem at hand and to find solutions (Renn 1999) to innovation related issues in which different value systems and interests are involved.

2.4.3.2.4 The Reflexivity dimension

Firms striving to innovate responsibly are faced with an environment characterized by: 1) constant changes (e.g. changes on customer needs and wants, societal expectations and values, technologies, competitor products, etc.) (Sicotte and Langley 2000; Hoegl and Parboteeah 2006) and 2) uncertainty about future events and/or the consequences resulting from innovation (Guston and Sarewitz 2002). In this context, Guston and Sarewitz (2002) argue that planning and perfect foresight are illusory as theory and practice have demonstrated that it is neither possible to anticipate all the potential impacts resulting from innovation nor how perceptions of stakeholders may evolve as they become aware of the

[8] Stakeholder deliberations are deliberations in which customers and/or stakeholders are involved

innovation. So, how to increase the chances of creating responsible outcomes when potential consequences of innovation are neither evident nor fully understood in advance?

Literature suggests that a useful mechanism to overcome the unpredictability inherent in innovation is the embedding of reflexivity in the innovation process (Guston and Sarewitz 2002). Reflexivity can be understood as an iterative process consisting of three components: reflection, planning and action/adaption (West 2000).

Reflexivity may support RI by facilitating the development of a new awareness among those in charge of innovation about the attributes of and relations between innovation and its context, as they evolve and interact. This may provide early insights about potential issues affecting the social, economic and/or environmental sustainability of outcomes. The generation of these insights allows adjusting, if necessary, the trajectories of innovation through incremental responses (Guston and Sarewitz 2002) in order to adapt its goals and features for enhancing its marketability, desirability and sustainability.

The deployment of reflexivity through the innovation process may involve 1) communicating with potential stakeholders in order to better understand evolving stakeholder capabilities, preferences and values, and 2) modulating, if necessary, the trajectories of innovation in response to the analysis of environmental information (Guston and Sarewitz 2002)

2.4.3.2.5 The Responsiveness dimension

Being responsive refers to the capability of those involved in innovation to react positively to and address different needs, requirements, views, issues and values (Singh 2012). In market-driven innovation projects, the attractiveness and therefore market success of outcomes is largely dependent on the firm's ability to be responsive to customer values and needs (Leonard and Rayport 1997; Narver, Slater et al. 2004). In RI, this responsiveness needs to be extended to *all* stakeholders in order to enhance the odds of generating innovation outcomes which embody the necessary values for social, economic and environmental sustainability (Ravesteijn, He et al. 2014).

The mechanisms of responsiveness involves the generation of knowledge about the views, perspectives, and framing of others (e.g. customers and other stakeholders), and the use of this knowledge to set the direction of and shape innovation (Owen, Stilgoe et al. 2013). On the other hand, responsiveness may be also observed in RI when firms react to emerging innovation related issues by changing the goals and/or features of innovation in order to enhance its ethical acceptability, social desirability and sustainability. Thus, the responsiveness dimension encourages firms to be both deliberative and adaptive (Owen, Stilgoe et al. 2013) to better understand and ensure care of the values that enhance the social, economic and environmental sustainability of outcomes.

2.4.3.3 Methods for the deployment of the five dimensions of RI

This subsection suggests a set of methods that firms can use to deploy the five dimensions of RI as suggested above. For the identification, it has been considered the insights generated through the review of the different approaches and models of innovation as well as the theoretical understanding of the five dimensions presented above.

2.4.3.3.1 Methods for the Anticipatory dimension

To facilitate the deployment of the Anticipatory dimension, there is necessary to identify methods which facilitate: 1) the identification and assessment of the consequences of prospective innovation, and 2) the generation of knowledge about the future developments which may shape the customers and societal values, and therefore the marketability, desirability and sustainability of outcomes.

Regarding the first group of methods supporting the deployment of the Anticipatory dimension, firms can use a wide range of quantitative and qualitative methods. The decision to use one method or another, and when, will depend on several factors: 1) the degree of concretion of the ideas, concepts or products of innovation[9] and 2) the level of knowledge and certainty about the potential cause-effect relationships between innovation and its context. Here, it is not my intention to provide a comprehensive list of all available methods, but to indicate some which may be useful to support RI. In particular, I will suggest certain methods to support firms that are dealing with emerging technologies[10] and, to a lesser extent, methods to support innovative projects in which there is previous knowledge about the potential consequences of innovation[11].

When dealing with emerging technologies based innovation[12], the anticipation and assessment of their potential effects upon certain values for sustainability, such as safety or environmental protection, may become a challenging task (Wardak, Gorman et al. 2008; Köhler and Som 2014). The newness of emerging technologies entails high levels of uncertainty regarding their potential effects and risks. This hinders the use of some risk assessment approaches which are based on scientific evidence and real word experience, such as empirical and model-based risk assessment approaches (Tzotzos, Head et al. 2009). Firms need then draw upon more qualitative methods in order to identify the potential intended and unintended effects of innovation. Among these methods, literature shows as scenarios analysis and

[9] This is related to stage of the innovation process in which the method can be used

[10] These innovations are particular interesting for RI as they entail high degree of uncertainty about their potential consequences.

[11] In this case, firms are faced with less uncertainty and it may be easier to anticipate the consequences resulting from innovation, and therefore, to deal with them before commercialization.

[12] Examples of these innovations are those based on nanotechnologies and materials, biotechnology or genetically modified organisms.

risk workshops can be helpful to identify, rank and assess the potential effects of innovation (Wardak, Gorman et al. 2008; Ackermann, Howick et al. 2014). Alternatively, business organizations can use the Delphi method, in order to identify and assess the potential effects of innovation by taking advantage of the knowledge of a more or less large number of experts (Markmann, Darkow et al. 2013). Another method which can be helpful for this purpose is desk research. Literature suggests that this method may enable firms to list the potential impacts of innovation by consulting the past experiences and problems associated with similar technologies and/or related industries[13] (Köhler and Som 2014). Overall, it would be recommended to deploy these methods at the early stages of the innovation process (i.e. the Front-End) in order to facilitate the design of strategies which avoid, or mitigate to levels acceptable by stakeholders, the potential consequences associated with innovative ideas and concepts.

Beyond the above methods, firms can also use quantitative methods to anticipate the potential impacts of innovation when there are previous scientific evidence and real world experiences with the technologies and systems involved. Among those methods, life cycle and risk assessment methods can be very helpful to deploy the Anticipatory dimension. In particular, the use of Environmental Life Cycle Assessment (LCA) methods can assist the design and development of innovation which contributes positively to environmental sustainability (Guinée 2002; Finnveden, Hauschild et al. 2009). Similarly, firms can conduct Social Life Cycle assessments (Dreyer, Hauschild et al. 2006; Jørgensen, Bocq et al. 2008; Benoît, Norris et al. 2010) to identify and assess potential issues which could affect values necessary for ensuring the social sustainability of outcomes. In some cases, it may be interesting to turn to more agile and easy to use life cycle methods, such as LInX (Khan, Sadiq et al. 2004). This, and similar existing methods, may be valuable options at the Front-End stage, when there is needed to support decision making in contexts in which available information may be imprecise and/or incomplete.

On the other hand, firms have available a wide range of methods that can be useful to identify and assess risks related to innovation outcomes. Some of these methods would include the Check list method, Brainstorming, What-if analysis, Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Hazard and Operability study (HAZOD) and Failure Mode Effect Analysis (FMEA), to name a few (Segismundo and Augusto Cauchick Miguel 2008; Fera and Macchiaroli 2010; Ding, Yu et al. 2012). In general, the use of these quantitative methods would be possible when there is enough available information regarding the innovation (i.e. its shape, materials and energy used, features, functionalities, etc.) and there is previous knowledge and certainty about the potential effects resulting from innovation. On the other

[13] For instance, firms could anticipate the potential impacts of an innovation, such as smart textiles, upon certain values by studying the deficiencies of the recycling processes of the textile industry, and learning from the risks associated with the end-of-life stage of electronic products or e-waste.

hand, methods such as simulations (Kirkpatrick, Simons et al. 2000; Crandall, Bhalla et al. 2002) can be useful at the Front-End and/or the Development stages to anticipate the consequences of innovation upon certain values, and to support the search of solutions which ensure a proper care of those values i for enhancing the social, economic and environmental sustainability of innovation.

Regarding the anticipation of future values which may shape the social, economic and environmental sustainability of the products of innovation, firms can use different foresight methods (Ruff 2006; Popper 2008). Literature suggests that firms can generate knowledge about future customers' values and needs through the deployment of methods such as trend scouting, expert workshops, interviews as well as the lead user method and/or by asking potential users through online survey (De Moor, Saritas et al. ; Ruff 2006; Churchill, Von Hippel et al. 2009; Rohrbeck and Gemünden 2011). On the other hand, political, economic, technological and societal developments which may affect stakeholders' values, could be foreseen through expert interviews, workshops, desk research and scenario methods (Ruff 2006). All in all, foresight methods may help firms in their attempt to innovation responsibly by providing information about stakeholders' values as well as the external opportunities and risks which needs to be properly considered to ensure the economic, environmental and social sustainability of innovation.

2.4.3.3.2 **Methods for the Participation dimension**

In this section, certain methods which enable the participation of stakeholders in the innovation process are suggested. In particular, I will indicate methods that allow firms to:

- Identify the stakeholders regarding innovation , and
- Stimulate and enable effective interactions between stakeholders from within and outside the firm's boundaries

The identification of stakeholders regarding innovation can be done through several methods. One of the most easy to deploy is brainstorming (Bryson 2004). However, the recognition of stakeholders which may be located at the periphery of the firm's operations, but whose values may need to be considered in order to enhance the social, economic and/or environmental sustainability of innovation, may require additional methods. Literature suggests that innovation teams can identify fringe stakeholders[14] (Hart and Sharma 2004) by using a snowball sampling method (O'Leary 2004), in which known stakeholders (suppliers, customers, NGOs, etc.) can be engaged in the identification process.

[14] Hart and Sharma (2004) refer as fringe stakeholder to the weak, poor, divergent, adversarial as well as non-legitimate, isolated, non-human and disinterested actors or groups located at the periphery of the firm's operational boundaries.

On the other hand, innovation teams striving to innovate responsibly have a wide range of available methods to engage with stakeholders through the innovation process. These engagement methods can be used to enable effective interactions which facilitate both the anticipation and understanding of stakeholders' values, needs and concerns as well as the generation and gathering of key resources (knowledge, skills, imagination, etc.) which may be necessary to generate responsible innovation. Table 3 below shows a set of methods identified in the innovation literature which can be used by firms to engage with their stakeholders. The mapping of participatory methods is according two dimensions: 1) the stage of the innovation process in which the method can be used and 2) the locus of participation. In terms of the stage of the innovation process, participatory methods supporting the Front-End stage or methods that will be used on later stages, such as the Development and the Commercialization stages are distinguished. Methods that could be used to deploy the Participatory dimension can also be classified in terms of the place in which interactions happen. Firms can choose between methods that facilitate face-to-face contacts or methods which enable virtual interactions through Internet-based and similar technologies. The selection of methods that enable one or the other type of interaction depends on which type of relationship is seeking (i.e. richness vs size and scope of the audience). In general, face-to-face methods stimulate rich interactions, in which participants may feel more willing to share information and knowledge than in virtual environments, in which privacy concerns may hinder information sharing (Sawhney, Verona et al. 2005). Furthermore, face-to-face methods may facilitate the generation of trust and commitment among stakeholders, which may pave the way for building collaborative relationships and partnerships for responsible innovation (Hemmati 2002; Van Huijstee and Glasbergen 2008).

On the other hand, virtual methods overcome some of the limitations of face-to-face methods (Sawhney, Verona et al. 2005). In particular, virtual methods allow tapping into the intelligence of a larger audience (Howe 2006) than face-to-face interactions, as well as increasing the duration and frequency of interactions with the stakeholders (Sawhney, Verona et al. 2005). Another particular characteristic of virtual methods is that they allow tapping into socially generated knowledge, as they facilitate interactions with communities of people with common interests.

Table 5 Potential methods to deploy the Participatory dimension

	Front-End Stage	Development and Commercialization Stages
Face-to-face interaction	• Interview, observation and experimental manipulation methods • Focus group discussions • Meetings, group discussions and round tables • Lead user • Scenario • Risk and innovation workshops	• Usability testing • Beta product testing • Meetings and Focus group discussions
Virtual interaction	• Virtual communities • Idea competitions • Idea management systems • Broadcast search platforms	• Web-based prototyping • Virtual product testing

Source: Own elaboration based on literature review

Firms have available certain methods which can be helpful for the identification and understanding of the stakeholders' values and concerns that need to be considered through the innovation process to enhance the social, economic and environmental sustainability of innovation. Literature suggests different social science research methods for these purposes. For instance, interviews, observations and experimental manipulations can be helpful methods to engage with stakeholders at the Front-End to generate key insights about customer values (Friedman, Kahn et al. 2002; Osterwalder, Pigneur et al. 2014). An additional method which can help firms to assess whether ideas and concepts have embodied correctly certain customer values is focus group discussion (McQuarrie and McIntyre 1986; Boddy 2005).

Apart from customers and users, literature suggests that firms can engage with other stakeholders through face-to-face methods in order to elicit their values and concerns regarding innovation. This may facilitate the consideration of this essential information through the innovation process to enhance the social, economic and environmental sustainability of innovation. Stakeholders may include, for instance, local communities affected or NGOs concerned with innovation, as well as fringe stakeholders (Hart and Sharma 2004). Among suggested methods for sharing information about innovation and working together in embedding certain values for sustainability in innovation, literature suggests meetings, group discussions and/or round tables (Van Huijstee and Glasbergen 2008; Ravesteijn, He et al. 2014; Arnold 2015).

Participatory methods can also support RI by facilitating the generation and gathering of key resources necessary for generating innovation outcomes which embed certain values reinforcing the social, economic and environmental sustainability of innovation. For this purpose, literature suggests certain

face-to-face methods which may be of special interest to support the development of key activities[15] at the Front-End, such as lead user (Von Hippel 1986; Churchill, Von Hippel et al. 2009), scenario analysis (Postma, Broekhuizen et al. 2012), and risk and innovation workshops (Wardak, Gorman et al. 2008; Arnold 2015; Carlsson, Hjelm et al. 2015).

Methods enabling virtual interactions among stakeholders can also be helpful for RI as they facilitate the identification of values and preferences of communities of users and give access to geographically-scattered resources (Sawhney, Verona et al. 2005). So, through engaging with communities, firms may be able to understand which values are relevant for the marketability, desirability and sustainability of ideas and prospective products. Moreover, firms can use virtual communities for assessing in a cheaper and faster manner, in comparison to alternative methods such as focus groups, whether concepts and products have embodied properly certain values.

Other virtual methods can be helpful for supporting certain activities at the Front-End. For instance, idea competitions (Arnold 2015) can be used to engage with, and encourage, stakeholders (employees, customers, suppliers, etc.) to generate innovative ideas or concepts which embody certain values for sustainability. Ideas can then be shared with stakeholders through collaborative idea management systems (Karlsson 2010) so that employees and/or customers can comment and enrich them in order to make them workable as well as economic, social, and environmentally sustainable.

On the other hand, if firms are faced with a lack of resources (knowledge, imagination, skills, etc.) for creating innovation outcomes which ensure care for certain values for sustainability, they may broadcast their challenges through online search platforms (Sawhney, Verona et al. 2005), such as Innocentive (www.innocentive.com) or Ninesigma (www.ninesigma.com), in order to find potential solutions among a large network of lead experts.

The methods deployed at the Development and Commercialization stages would mainly be used to validate whether innovation outcomes have embodied properly certain values, or if they generate any concern which requires attention in order to enhance sustainability of outcomes. Both face-to-face and virtual methods, such as usability testing (Buur and Bagger 1999), beta product testing (Dolan and Matthews 1993) as well as web-based prototyping and virtual product testing (Sawhney, Verona et al. 2005), can be used to engage with customers in product validation processes. These methods provide valuable information about customer's reactions to prospective innovation outcomes before they are

[15] For instance, the mentioned methods can be useful to generate new ideas which embed certain values for sustainability, but also to identify risks and implications of innovation upon certain values which need to be taken care for avoiding market failure and/or societal contestation.

launched. Any negative reaction and/or concern should be then carefully considered as it may point to values which have not been properly embedded in innovation.

Finally, the engagement of other stakeholders, such as NGOs and local communities affected and/or concerned with innovation outcomes, throughout the Development and Commercialization stages, may be key for RI, and especially when firms are working with potentially controversial technologies or large project with a significant impacts upon stakeholders' way of living, such as genetically modified organisms (von Schomberg 2013) or large infrastructure facilities (Ravesteijn, He et al. 2014). Literature suggests to engage with these stakeholders through focus group discussions and/or meetings in order to share information about innovation, to identify potential concerns about innovation outcomes and/or collect expert information about actions which could be taken in order to enhance the sustainability of outcomes (Van Huijstee and Glasbergen 2008).

2.4.3.3.3 Methods for the Deliberation dimension

Literature suggests a wide range of methods which can be used for deploying the Deliberation dimension. These methods could be mapped according to two dimensions: 1) the number of stakeholders involved in deliberations, and 2) the locus in which deliberation has place. According to the first dimension, methods can be classified as methods that enable a one-to-one dialogue[16] and others that facilitate multi-stakeholder deliberations. On the other hand, stakeholders can dialogue through face-to-face interactions or through virtual environments supported by Internet-based and similar technologies. Table 4 below shows a set of methods identified in literature and classified according to the two dimensions mentioned above. The list does not pretend to be comprehensive but to show a variety of methods that may support Responsible Innovation[17]. Next, it would be briefly discussed when innovators may deploy one or another method, and how they can support RI.

[16] For instance, dialogues between employees, dialogues with customers, or NPOs, etc

[17] Additional methods that may support the Deliberation dimension have already been discussed in the Participatory dimension. Thus, methods such as workshops and scenario analysis can be used to facilitate deliberations between innovators, as well as innovators and their stakeholders.

Table 6 Mapping of methods that may be used to foster deliberations through the innovation process

		Locus of deliberation	
		Face-to-face	**Virtual environments**
Number of stake-holders involved	**Multiple-stakeholders**	Roundtables Focus group discussions	Virtual Communities Web-based software systems (e.g. Idea management systems, virtual prototyping, and virtual product testing)
	One-to-one	Usability testing Scenario analysis Meetings	Intranet-based software systems

Source: Own elaboration based on literature review

Regarding face-to-face methods, firms can use meetings to engage in dialogues with diverse stakeholders, such as NPOs (Non-Profit Organizations) or other business organizations. Meetings can be used to generate explorative dialogues that support the building of relationships and partnerships (Van Huijstee and Glasbergen 2008) necessary for effectively integrating key stakeholders in the innovation process. They may also help firm to get valuable stakeholder's knowledge and opinions which enhance the embedding of certain values for sustainability in innovation. Meetings may be used at different stages of the innovation process to deal with innovation-related issues as they emerge.

Another potentially interesting method for the deployment of the Deliberation dimension is scenario analysis. This method can be deployed to support key elements of the Front-End, such as opportunity identification and analysis, or ideas generation and enrichment (Koen, Ajamian et al. 2002; Postma, Broekhuizen et al. 2012). Through scenarios, innovators can engage with different stakeholders[18] in order to 1) generate new ideas and develop them through a collective process of rational discussion in which different value systems and perspectives are integrated; 2) discuss the pros and cons of ideas regarding ongoing or future situations from multiple perspectives necessary to ensure the social, economic and environmental sustainability of outcomes, 3) evaluate risks and their potential implications upon certain values necessary for sustainability.

Literature also suggests that usability testing with users can support firms to elicit sticky information and knowledge (Von Hippel 2005) that would be otherwise difficult to obtain (Buur and Bagger 1999). Thus, usability testing can be used to identify and understand customer's preferences and values, and to integrate these learnings into the design and development processes in order to enhance desirability, acceptability and sustainability of innovation.

[18] From within and outside the firm's boundaries.

On the other hand, and as already mentioned in the Participatory dimension, firms can use methods such as focus group discussions to understand customer and other stakeholders' values which may be essential for enhancing the acceptability, desirability and sustainability of outcomes (McQuarrie and McIntyre 1986; Van Huijstee and Glasbergen 2008).

The last of the face-to-face deliberation methods suggested is the roundtable. Roundtables may involve a wide range of stakeholders, including firms, policy-makers and NPOs. Roundtables may be deployed in order to agree among stakeholders which requirements innovation should fulfil in order to care and ensure care of certain values for social, economic or environmental sustainability (Van Huijstee and Glasbergen 2008; Laurance, Koh et al. 2010). Roundtables may not be directly linked to a particular innovation process, but they may provide valuable learnings that firms should use to generate responsible innovation.

Apart from the face-to-face deliberation methods, firms have a set of virtual methods available that allow the establishment of a fluid and rich dialogue with diverse stakeholders, and especially with their current and potential customers (Sawhney, Verona et al. 2005). These methods, as already discussed in the Participatory dimensions, allow firms to establish a deliberation process without the limitations and costs associated with face-to-face interactions[19]. Firms may use virtual methods to foster learnings and the generation of insights about values held by communities, as well as to evolve ideas through the contribution of stakeholders so that the relevant values for sustainability are properly considered and embedded in innovation.

2.4.3.3.4 Methods for the Reflexivity dimension

Organizational research theories suggest that reflexivity may be stimulated through a wide range of actions, such as questioning, exploratory learning, analysis as well as diversive exploration and reviewing past events with self-awareness (West 2000). Considering these options, and in line with the theoretical explanation of the Reflexivity dimension, certain methods are proposed hereafter. In particular, especial attention it is given to methods that may facilitate the exploration and monitoring of the environment as well as the analysis of, and reflection on, certain issues which may be relevant for RI.

Exploration and monitoring of the environment are essential to obtain and develop insights and information which may enable the shaping of innovation according to the current and anticipated environment. The issues to monitor in order to innovate responsibly may be numerous and varied.

[19] Limitations of face-to-face methods refer mainly to the number of lower number of participants involved as well as the shorter duration of the deliberation process, in comparison with virtual methods. Virtual methods may save time, reduces costs and allows for a high number of iterations with stakeholders through the innovation process.

Some of these issues include the identification of 1) values, expectations and concerns of stakeholders; 2) potential consequences and risks related to innovation; and 3) future developments that may have an influence on the individual and social values. As issues 2) and 3) have been already mentioned in previous dimensions, hereafter I will focus on methods that firms can use to identify stakeholders' values and concerns.

At the Front-End stage, firms can use a wide range of methods to support reflection on stakeholder's values, expectations and concerns. Widely used methods for gathering information about stakeholders include interviews, focus groups, desk research[20], surveys as well as field observations, experimental manipulations, prototyping or discussions/meetings with stakeholders (Friedman, Kahn et al. 2002; Guston and Sarewitz 2002; Van Huijstee and Glasbergen 2008; Osterwalder, Pigneur et al. 2014). The outputs of these methods can be used in workshops, brainstorming sessions as well as scenario analysis as raw material to facilitate reflection on issues such as 1) unmet values and needs and 2) the wide impacts of products of innovation and their effects on values relevant for the economic, social and environmental sustainability of outcomes. Furthermore, certain foresight methods, such as future trend analysis as well as expert workshops (Ruff 2006) can be used to stimulate reflexivity on the future desirability, acceptability and/or sustainability of innovation outcomes.

As the innovation process advances, innovators can deploy reflexive processes to assess the sustainability of innovation solutions. Different methods, depending on the level of definition of innovation, could be used in order to get feedback from stakeholders, reflect on it, and understand which features of innovation are appreciated or generating concerns. Some methods which are especially used with customers include concept testing (Moore 1982), virtual and face-to-face prototyping testing (Rettig 1994; Sawhney, Verona et al. 2005; Hartmann, Klemmer et al. 2006), virtual and face-to-face customer tests of products (Dolan and Matthews 1993; Sawhney, Verona et al. 2005), product clinics (Dolan and Matthews 1993) and usability testing (Buur and Bagger 1999; Dumas 1999; Barnum and Dragga 2001; Rubin and Chisnell 2008). To identify and understand concerns about innovation from other stakeholders which may be affected by innovation (NGOs, local communities, etc.) firms may turn to methods already suggested in the Participation and Deliberation dimensions, such as meetings and focus group (Van Huijstee and Glasbergen 2008).

2.4.3.3.5 **Methods for the Responsiveness dimension**

Overall, responsiveness can be understood as action taken in response to environmental information that is captured and disseminated across the firm's departments (Kohli, Jaworski et al. 1993). So, the

[20] This includes context analysis of media sources for public information about the innovation, for instance

Responsiveness dimension can be deployed to support RI through a wide range of methods which stimulate firms to:

- Generate knowledge about the views, perspectives, and framing of others. Useful methods for this purpose have been already suggested in the Anticipation, Participation, Deliberation and Reflexivity dimensions, such as focus groups, meetings, trend analysis or user testing, to mention a few;
- Disseminate the captured information across the firm's departments. Methods that can be helpful to foster the dissemination of information are interdepartmental meetings, interdepartmental cooperation (Sinkula 1994) as well as cross-functional teams;
- Stimulate the performance of activities aimed at enhancing the attractiveness, acceptability and sustainability of innovation outcomes. This may involve making certain changes on design and/or development of innovation to facilitate that all stakeholders' values are ensured care. It may also involve the adoption of new methods and processes for designing, developing and/or producing innovation outcomes in such a way that certain values for economic, environmental and social sustainability are better embedded in innovation outcomes. For instance, firms may adopt Design for Environment approaches or Life Cycle methods in order to create innovations which better respond to societal pressures for more environmentally-friendly solutions (Pujari 2006; Adams, Bessant et al. 2012). Similarly, firms may respond to societal demands for more fair distribution of the benefits and costs of innovation on society by adopting social impact assessment methodologies (Vanclay 2003) and using their outcomes to shape innovation so that stakeholders' values are better protected and ensured.

2.4.3.3.6 An evolved a Theoretical Framework for RI

The framework for RI suggested by Singh (2012) was selected as the most suitable to provide a Theoretical Framework for exploring the research questions defined in this dissertation. This framework consists of three main elements:

1) Being caring and ensuring care for certain values
2) Ensuring the goals of social, environmental and economic sustainability
3) Five dimensions of responsible innovation

The framework for RI proposed by Singh (2012) states that firms need to consider certain issues to innovate responsibly. In particular, the framework suggests that firms ought to care and ensure care of certain values. The search of the values for RI is guided by the goal of social, economic and

environmental sustainability. Therefore, innovators have to ensure care of those stakeholders' values necessary for achieving this goal.

As a new and developing approach, the framework for RI showed certain limitations which called for further development. Therefore, in previous subsections (2.4.3.2 and 2.4.3.3), every dimension of Singh (2012)'s framework has been further explored in order to understand why and how they support the generation of responsible innovation. This provides a more detailed understanding of the main mechanisms which would be expected to be considered through the innovation process for RI. Based on this understanding, it has been suggested a set of methods which may allow firms to deploy the five dimensions through the innovation process. Below, Table 7 summarizes the main elements of the Theoretical Framework developed for this dissertation.

Table 7. Key elements of the Theoretical Framework for RI

	Innovation Process Stages		
Dimensions for caring and ensuring care…	**Front-End**	**Development**	**Commercialization**
Anticipation of: • intended and unintended effects of innovation • future values of customers and stakeholders • future technological, political and otherwise developments	Scenarios Risk workshops Delphi method Desk research LInX Simulations Foresight methods	LCA and SLCA Check lists What-if analysis Fault and event tree analysis Failure Mode effect analysis Hazard and Operability study Simulations	
Participation of stakeholders to: • identify and consider the stakeholders' values necessary for social, economic and environmental sustainability • generate, screen and/or assess innovative ideas and concepts which embody certain values for sustainability • test the acceptability, desirability and/or sustainability of prospective outcomes • identify potential risks resulting from innovation • gather key resources for the embedding of certain values for sustainability in innovation	Brainstorming Snowball sampling Interviews, observation and experimental manipulation Focus group discussions Meetings and round tables Lead user Scenarios Risks and Innovation workshops Virtual communities Idea competitions Broadcast search platforms	Usability testing Beta product testing Meetings and focus group Web-based prototyping Virtual product testing	

Dimensions for caring and ensuring care…	Innovation Process Stages		
	Front-End	**Development**	**Commercialization**
Deliberation with stakeholders to: • enable decision-making processes in which innovation related issues are considered from multiple values and perspective • identify stakeholders values and concerns with regard to innovation • identify key requirements for the marketability and sustainability of products of innovation • enhance understanding of problems and look for solutions which aim to social, economic and environmental sustainability	Meetings Scenario analysis Round tables Focus group discussions Intranet-based software systems Virtual communities Web-based software systems	Meetings Round tables Usability testing Focus group discussions Virtual communities Intranet-based software systems	
Reflexivity to: • develop awareness about the innovation as well as their potential consequences upon the environment • develop awareness about the customers and other stakeholders, the environment and changes occurring in it • plan for adaptation to enhance social, economic and environmental sustainability	Interviews Focus group Desk research Surveys Field observation Experimental manipulations Prototyping Discussions/meeting with stakeholders Workshops Brainstormings Scenario analysis Expert and risks workshops	Concept testing Virtual and face-to-face prototyping testing Virtual and face-to-face customer tests of products Product clinics Usability testing Meetings Focus group LCA and SLCA	

	Innovation Process Stages		
Dimensions for caring and ensuring care…	**Front-End**	**Development**	**Commercialization**
Responsiveness through: • Generating knowledge about the views, perspectives and framing of others so that it is possible to understand the values and concerns with regard to innovation that would affect the social, economic and environmental sustainability. • changing the goals and/or features of innovation outcomes to adapt them in front of new information or insights about impacts of innovation so that it is enhanced its social, economic and environmental sustainability		Focus group Meetings Trend analysis User testing Meetings Cooperation Cross-functional teams Design for Environment or for Sustainability LCA and SLCA	
…of certain values for social, environmental and economic sustainability			

Source: Own elaboration

2.5 Conclusions

After an extensive literature review, this chapter has developed a theoretical framework for understanding how firms can innovate more responsible, i.e. to generate outcomes which embody certain values for social, economic and environmental sustainability. Before delving into the models and approaches, the chapter reviewed the concept of responsibility and developed a working definition of responsible innovation for this research. Then, existing theories and approaches of innovation were reviewed, including Linear and Interactive models, Innovation Systems Models (NIS, SIS and TIS), Open Innovation Model, Sustainable Innovation approach and Responsible Innovation (RI) approach. The analysis performed shows that Responsible Innovation is the most suitable approach to provide a framework for explaining how firms can deal with responsibility issues through the innovation process. In particular, the framework proposed by Singh (2012) has been adopted as the theoretical framework which better addresses the second research question of this dissertation.

The framework for RI suggests certain mechanisms that firms need to consider for the generation of RI: 1) Being caring and ensuring care for certain values; 2) Ensuring the goals of social, environmental and economic sustainability and 3) make the innovation process follow five dimensions: anticipation, participation, deliberation, reflexivity and responsiveness. On the other hand, different methods have been proposed for deploying the five dimensions and thus to enhance our understanding on how responsible innovation can be implemented at the firm-level.

The evolved framework for RI seems a promising *tool* to explain and understand how firms can generate RI. In any case, this is an emerging framework which has been empirically validated only with regard to particular technologies and contexts (e.g. developing countries). Therefore, in other to achieve the research objective of this thesis, it would be necessary to validate whether the adopted framework can explain RI in other contexts. For that, examples of innovations from the car industry will be analysed in Chapter 4 to 6. Before that, Chapter 3 presents the research design and methodology elaborated to deal with the empirical research part of this thesis.

3 Research Methodology

3.1 Defining the research focus

In Chapter 1, the research focus of this thesis was briefly introduced. Now, once a definition and a theoretical framework for responsible innovation have been developed (Chapter 2), it is important to come back to the research focus and to specify it more precisely. This may help focus the object of this research as well as the development of propositions to be tested through the empirical research part of this thesis.

As already introduced in Chapter 1, the main aim of this research is to propose and validate a framework that facilitate the generation of responsible innovation. To achieve this aim, the following questions have been elaborated to guide this research:

1. Which definition of the concept of innovation can become a working definition for this research?
2. How could responsibility issues be embedded through innovation processes to facilitate the generation of responsible innovation according to exiting theories and models of innovation?
3. How has responsible innovation been deployed at the firm-level?
4. Are mechanisms to support firms to innovate more responsibly confirmed through empirical evidence?

Briefly, research questions 1 and 2 would require the review of literature in search of suitable concepts, theories and models that can be useful for defining and explaining responsible innovation. On the other hand, research questions 3 and 4 refer to the empirical part of this research. In this chapter, a research design and methodology will be proposed to deal with these last research questions.

Responsible innovation has been defined as a process in which those involved (firms, research institutions, regulators, etc.) care and ensure care for certain values for social, economic and environmental sustainability for bringing a new or improved product, process, service, method or way of organizing in a specific market or context..

The focus of this research is on analysing innovation processes that produce responsible innovation and on determining what mechanisms contribute to the generation of outcomes that embody certain values for social, economic and environmental sustainability. For analysing innovation processes and enabling the identification of mechanisms for RI, a theoretical framework has been developed in Chapter 2. This provides interesting insights about what may be expected in an innovation process to support the

generation of RI. The framework states that RI results from an innovation process in which five dimensions need to be present. These dimensions are anticipation, participation, deliberation, reflexivity and responsiveness. According to the adopted framework, dimensions would enable firms to identify and embed in innovation certain values for social, economic and environmental sustainability. Figure 6 presents a model of how RI may be generated at the firm-level according to the theoretical framework just outlined.

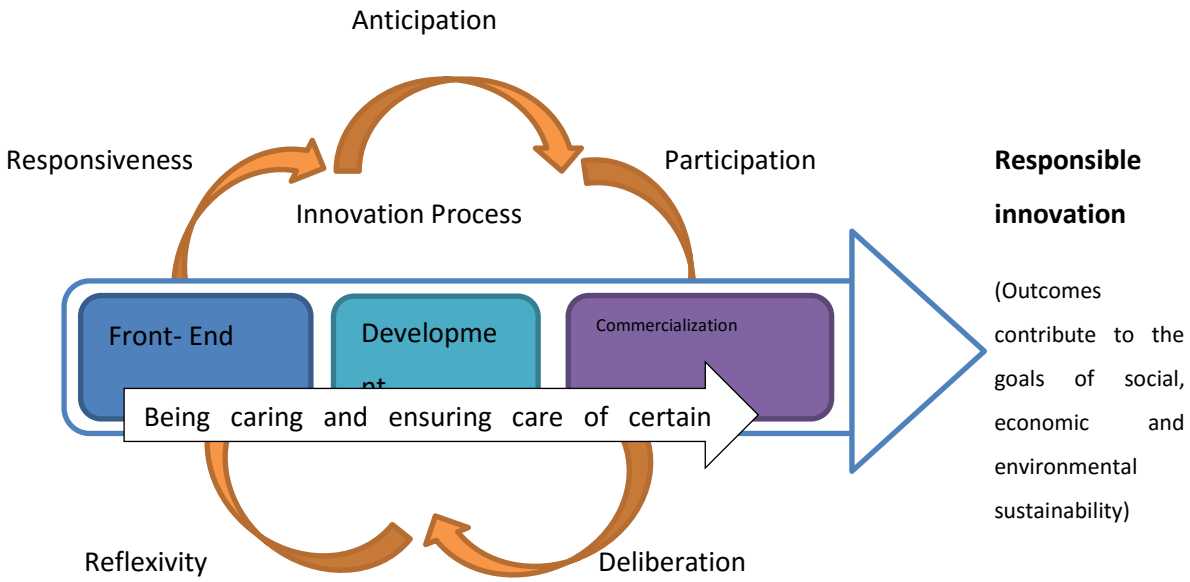

Figure 6. The innovation process, the mechanisms to embed responsibility issues and outcomes of the process (Source: own elaboration)

My interest in the empirical part of this research is testing whether the above model is suitable to explain how firms can embed responsibility issues through the innovation process in order to generate RI. This is needed since the theories in which the model is based, although derived from empirical observations, have been validated in few contexts and cases (Singh 2012). Therefore, it would be interesting to evaluate whether the theories suggested by Singh (2012) can be validated by empirical evidences from different innovations and contexts. To evaluate these theories a research design is proposed in next section.

3.2 Research Design and Methodology

3.2.1 Research Design

Research or methodological design refers to the *plan* or *blueprint* established by the researcher for the collection, measurement and analysis of data in order to conduct research (Kothari 2004; O'Leary 2004). Before I describe the research design that has been adopted to conduct this research, it is important to justify why the case study approach has been deemed as the most appropriate methodological framework for this research.

As described in the previous section, the validation of the mechanisms for RI showed in Figure 6 requires testing whether empirical evidences support them or not. These evidences could be *observed* by analysing how responsible innovations have been deployed so far. This would require the analysis of the innovation processes, which resulted in responsible innovation, in order to uncover what mechanisms were used to shape innovation.

The analysis of innovation processes requires an appropriate research strategy. Innovation processes can be considered complex phenomena whose boundaries cannot be clearly distinguished from the context. Further, this research calls for an *ex-post* analysis of innovation processes. This implies that the researcher has little or no control over the events under investigation. To study this kind of phenomena, literature suggests that case study is the most suitable research strategy (Yin 2003).

An important decision to make with regard to research design when adopting a case study strategy is whether it would be more suitable to conduct a single-case or a multiple-case study (Yin 2003). In this research, a multiple-case study design is preferred as this enables the selection and analysis of several innovation processes resulting in responsible innovation. The analysis of these cases may provide evidence about the potential mechanisms used for embedding responsibility through the processes. If two or more cases provide convergent evidence about certain mechanisms, then it would be possible to more make robust and compelling claims about the validity of the findings, in comparison with those derived from a single-case study (Yin 2003).

Based on the multiple-case study design proposed by Yin (2003), a research procedure has been adopted for conducting the empirical research of this dissertation (see Figure 7) The procedure begins with the development of a theoretical framework for RI[21]. Based on this, several theoretical propositions indicating how firms may embed responsibility issues through the innovation process have been elaborated (see Section 3.2.2 in this Chapter). Then, a second step entails the selection of cases (see

[21] The theoretical framework was developed and presented in Chapter 2

Section 3.2.3 for a description of the selection process). Then, three case studies are analysed individually (Chapter 4-6). Next step encompasses a cross-case analysis, which provides the basis for evaluation and modification of the theoretical propositions (Chapter 7). On the basis of this analysis, conclusions and recommendations will be drawn (Chapter 8).

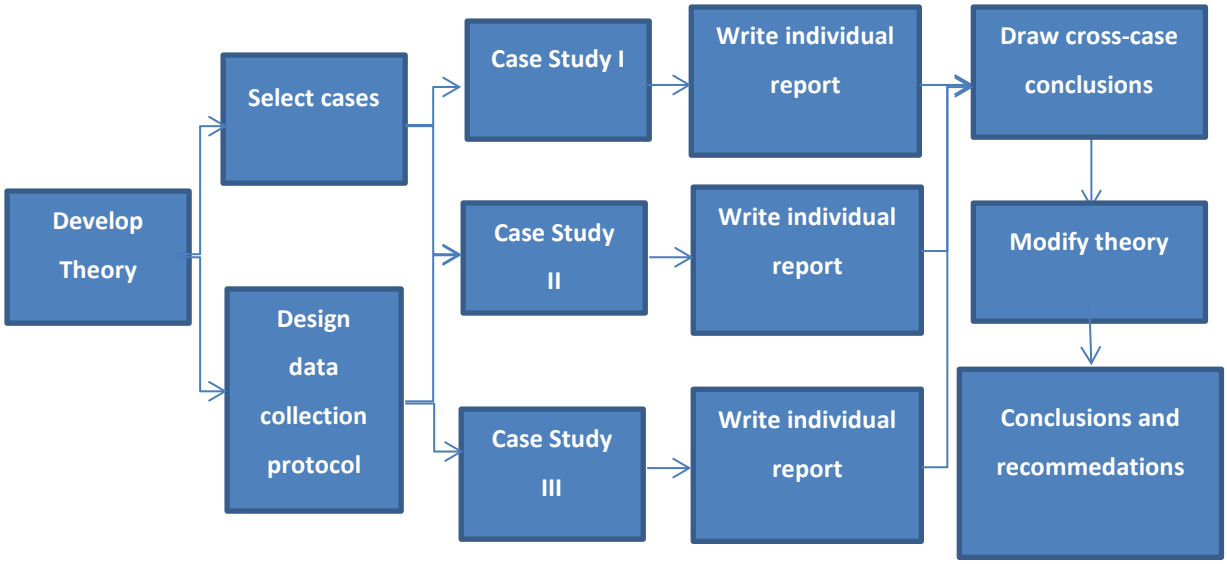

Figure 7. Research procedure adopted for this research (Adapted from Yin (2003))

3.2.2 Propositions

As mentioned earlier in this chapter, my research interest is to determine what mechanisms can be useful for generating responsible innovation at the firm-level. For achieving this, in Chapter 2 I have looked for a theoretical framework encompassing a set of mechanisms which may be useful for supporting firms in their efforts to innovate responsibly. Although promising, the mechanisms identified in the literature have been validated only in a few cases (Singh 2012). Therefore, in order to achieve the objective of this research it would be necessary to test whether there is evidence that validate the usefulness of the five dimensions to generate responsible innovation.

In order to test the theoretical framework developed in Chapter 2, in this section I elaborate a set of propositions. These propositions suggest how each dimension (i.e. anticipation, participation, deliberation, reflexivity and responsiveness) may contribute to the generation of responsible innovation. On the other hand, a last proposition is put forward indicating the potential relationship between the five dimensions, values for sustainability and the generation of responsible innovation.

Anticipation dimension

P1A: The analysis in an anticipated manner of the potential consequences of innovation results in making decision to exploit the positive impacts upon values for sustainability, and/or to mitigate or avoid the negative ones.

P1B: The generation of knowledge about the context in which innovation will be deployed results in efforts to embed in innovation those values which may determine the acceptability, desirability and sustainability of innovation outcomes.

Participation dimension

P2: The participation of stakeholders through the innovation process enables tapping into resources (knowledge, ideas, technologies, networking, etc.) necessary for enhancing economic, social and/or environmental sustainability.

Deliberation dimension

P3: Deliberations among stakeholders through the innovation process results in decision making which increase the acceptability, desirability and sustainability of innovation outcomes.

Reflexivity dimensions

P4: The analysis of the cause-effect relationships between innovation and the context facilitates the identification of impacts resulting from innovation and the adoption of measures to maximise the positive ones and/or mitigate or avoid the negative ones.

Responsiveness dimension

P5: The consideration of the values, needs and legitimate interests of stakeholders through the innovation process it enhances social, economic and environmental sustainability, and reduces risks of societal contestation.

Propositions relating the dimensions with the outcome of the innovation process

P6: Responsible innovation occurs if only if the innovation process follows the anticipation, participation, deliberation, reflexivity and responsiveness dimensions.

3.2.3 Selection of cases

For the exploration of how responsible innovation may be deployed in real setting, the car industry was selected as the industry which can provide interesting innovations to explore. Two reasons are behind this decision. First, the car industry is the origin of a constant flow of innovations resulting from a complex network of actors: car makers, suppliers, regulators, driver and consumer associations, companies operating in other industries, such as mobile devices, etc. Among those innovations, in the last years the car industry has provided interesting examples of innovations created to enhance the sustainability of the road transportation system[22]. Electric vehicles, new safety systems and the embedding of new information and communication systems in vehicles are some examples of systems and technologies which have been commercialized to embed in vehicles certain values (e.g. environmental friendliness and safety). Thus, this researcher believed that the exploration of some of these cases may provide new and interesting evidence about the mechanisms used to embed responsibility issues through the innovation process.

On the other hand, accessibility to relevant data about complex innovation processes and their contexts was the second reasons that made this researcher opt for the car industry and no other. For three years, this researcher was a part of the Innovation Department at a car maker, SEAT. Thanks to that position, I have had access to an environment which enabled me studying in-depth how innovations are created and developed in this particular and relevant industry.

To select which cases to explore in search for evidence about responsible innovation, I followed the procedure described below:

- First, I explored for innovations that the car maker was working on or had commercialized in the last five years[23]. As result of this exploration, a first list of 21 innovations was created[24].
- Then, I looked for information about the main features of the identified innovations through informal contacts with managers, engineers, product managers and marketers who were involved or knew about the different innovations.
- Next, two criteria were used to screen and select the innovations which would be evaluated:

[22] With this argument, the researcher does not pretend to state the car industry is near to become sustainable. In fact, the car industry is faced with important economic, environmental and social sustainability challenges that require fundamental changes on how the industry has been operating so far. For an analysis of the sustainability challenges of the car industry, the reader may refer to the book 'The automotive industry and the environment' (Nieuwenhuis and Wells 2003)

[23] The time frame was an important issue in the selection process mainly because old cases offered fewer chances to get in contact with the actors who were involved in the different innovation processes.

[24] The list of innovations is not provided for confidentiality reasons. Only one case, the Multi-Collision Brake system (MCS) is explicitly referred throughout this thesis.

- The innovation had to embody in a distinctive manner certain values for sustainability of road transportation, such as safety and/or environmental friendliness. Therefore, innovations were selected following a literal rather than for theoretical replication logic (Yin 2003).
- Key participants in the creation and development of the innovation could be identified and were available for data collection.

As a result of this procedure, three innovations were selected as potential instances of responsible innovation:

- The commercialization of Electric Vehicles (EVs) in the Spanish market
- The commercialization of two Advanced Driver Assistance Systems (ADASs)
- The commercialization of a new safety system called Multi-Collision Brake (MCB) system

3.2.4 Research methodology

Here, I describe the different methods used to collect and analysis empirical data. Finally, a brief description is provided about how the case study reports are organized in this dissertation.

3.2.4.1 Data collection

To develop a deep understanding of the innovation processes investigated as well as to ensure the triangulation of evidence from several sources, multiple data collection methods were deployed (Yin 2003; Hernández Sampieri, Fernández-Collado et al. 2006). The main methods used for data collection were the following:

- Participant-observation (Yin 2003): In the Electric Vehicle case study, the researcher was part of the team in charge of carrying out the project for commercialization of this vehicle. This provided an extraordinary opportunity to gather data by observing the different activities carried out during the process, from conception to conclusion.
- Semi-structure interviews: In the ADASs and Multi-Collision Brake case studies, face-to-face, semi-structure interviews were used to collect data about the two innovation processes as well as their contexts. Interviewees included managers, engineers, developers, marketers, product managers and staff from other relevant areas of the companies involved in the ideation, development and/or commercialization of the selected innovation processes. Further, researcher had contacts with interviewees, and other key participants in the different innovation process, through telephone and emails to clarify any issue arising after the

reviewing and analysis of the data. In Appendix A and B, the reader can find the interview checklist used and the list of interviewes [25].

- Document analysis (O'Leary 2004): Internal documents such as meeting minutes, presentations, emails as well as results from different workshops related to the cases were gathered and analysed. Further, public information published in Internet was used when available.

3.2.4.2 Data analysis and case study reporting

The analysis of the case studies was organized around the three elements for responsible innovation described in the framework developed in Chapter 2. Thus, the following three questions were elaborated to guide the analysis of the cases:

- How the innovation process was conducted and dimensions for responsible innovation followed?
- What and how values were considered and ensured care through the innovation process?
- How goals for social, economic and environmental sustainability were achieved?

For analysing the data, it was decided that the most appropriate method was that of pattern matching (Yin 2003).Thus, I searched for patterns in the collected data and compared them with the patterns suggested by the theoretical framework to check whether they were consistent or not.

With regard to case study reporting, this was organized as follows:

- An introduction of the case
- A description of the innovation outcomes as well as the background of the case
- An analysis of the innovation process and outcomes it terms of i) how dimensions were followed, ii) what and how values were considered throughout the innovation process and iii) how goals for environmental, economic and social sustainability were achieved.
- Conclusions

Table 8 below summarizes the measures adopted by this researcher to meet the criteria for a quality case study research as suggested by Yin (2003).

[25] The list does not show informal contacts made with different staff working at SEAT and the VW group but who contributed to clarify doubts and to understand better the complex process of developing a new vehicle.

Table 8. Summary of measures adopted to meet the quality criteria for case study research

Criterion	Tactics suggested by literature	Measures adopted to meet the criteria
Construct validity	Use of multiple sources of evidence	Participant observation and data from interviews were triangulated with data from multiple documents, including reports, emails, presentations and Internet.
	Establishing a chain of evidence	Detailed processual narrative developed.
	Key informants review draft case study report	At least one key participant in each case study was asked to review a draft of the case study report.
Internal validity	Pattern-matching	Empirically based patterns are compared with patterns suggested by theory.
	Explanation-building	No relevant in this research as I'm testing theory
External validity	Use replication logic in multiple-case studies	Three cases were analysed in order to ensure a robust analysis of the mechanisms for responsible innovation
Reliability	Case study protocol	A protocol was designed to guide the data collection process.
	Case study database	A data base involving reports, notes, templates and outcomes of different activities related to the case was created.

Source: Adapted from (Yin 2003)

In this chapter it has been described the research focus for this dissertation. Based on it, I have argued that the best research design to deal with the research questions is a multiple-case study design. Next, the research procedure for conducting this research has been presented. This procedure involved the elaboration of theoretical propositions to be tested through the case studies. Then, three cases from the car industry have been selected to investigate how responsible innovation can be deployed. Finally, the research methodology adopted in this thesis has been elaborated and justified.

4 The commercialization of electric vehicles

4.1 Introduction

Electric vehicles (EVs) are considered a potential solution to tackle environmental and social challenges associated with mobility, such as climate change and the air pollution in urban areas[26]. However and despite the potential benefits associated with this technology, the weak consideration of societal needs during the innovation process has hindered their adoption by society[27] so far (van den Hoven and Jacob 2013). This has raised a debate on how EVs can be introduced more responsibly to accelerate their adoption so as to reduce environmental and social impacts resulting from road traffic. In order to contribute to this debate, this chapter focusses on an innovation project aimed at exploring and creating new ways for the commercialization of EVs in the Spanish market. The innovation project started in September 2011 and ended in July 2012[28].

The case is being considered for assessing whether it would be an evidence for responsible innovation approach. Therefore, in this chapter it will be explored how the innovation project was conducted and how the dimensions of responsible innovation were followed to embed certain values in innovation (Section 4.3.1). Then, it will be analysed which values were considered and ensured care through the process (Section 0) and how the embedment of these values contributed to social, economic and environmental sustainability (Section 4.3.3). Finally, conclusions will be presented in Section 4.4.

Next, and before delving into the analysis of the case, Section 4.2 will present a description of the background of the case and a brief description of innovation outcomes.

4.2 Description of the case

In 2011, SEAT, the Spanish brand of the Volkswagen Group (VW group, hereafter), was analysing the commercialization feasibility of electric vehicles (EVs). The commercialization of EVs was part of the SEAT long-term strategy to reduce the CO_2 emissions of its car fleet, a legal requirement to fight against climate change. One of the EVs models being analysed for being sold in the Spanish market was a small

[26] According to the European Commission 430.000 people die prematurely in Europe-28 in 2011 due to air pollution, which is produced to a large extent by road traffic (EEA 2014).

[27] In Spain, the government expected that in 2011 the number of electric cars sold would be around 12.000 units. That year, 197 units were sold in Spain, representing the 1.6% of the expected sales. Nowadays this type of vehicles represents a minimum share of the vehicles sold every year yet.

[28] The project mission milestone was approved and a second phase started in July 2012. This second phase ended in 2014 with a proposal supported by three companies to deploy the service. In any case, Top management decided not to implement the service due to a change on the strategy with regards to EVs.

car, intended for both private and corporate customers demanding a practical vehicle to move in urban areas. The EV was equipped with a portable infotainment that included GPS navigation, radio, and other more or less commercially standard features.

Before making a decision on commercializing the new EV, the Marketing department conducted a market assessment in Spain. The results of the assessment revealed that there was virtually no demand for such vehicles. Potential customers, especially fleet managers, were reluctant to buy a vehicle which was more expensive and had a lower performance than their conventional counterparts. The inexistent market demand in Spain of EV put in risk the project feasibility, which did not have a strong financial situation to afford the introduction of the EV at a loss.

In front of the no-demand situation, SEAT questioned the idea of commercializing the EV using the traditional business model and undertook a project aimed at creating more innovative ways of commercializing this emerging technology. The design of new ways of commercializing EVs involved multiple stakeholders, from the stage of opportunity identification to the concept development and test. The main stakeholders included were the following: potential customers, local public administrations, firms operating in the tourism, energy and infrastructure management industries as well as suppliers, consultants, healthcare organizations and software experts. During the project, SEAT, a company operating in the tourism industry and different experts collaborated in the design and development of a new mobility service based on EVs. The new mobility service entailed many innovations. The service included: electric vehicles connected to Internet, a vehicle recharging system powered by renewable energy, on board infotainment systems that supplied information on the environment as well as managed the sale of cultural and sporting events, and a back-office system capable of managing the charge of the EVs and providing assistance to customers in case of any contingency. The service was aimed at tourists visiting Spanish cities and allowed doing sightseeing tours in an independent and environmentally-friendly way. Furthermore, the service allowed users to get information about local tourist and cultural sites and, if they wished, buy tickets from an app.

The design of new ways of commercializing EVs was an interactive and iterative process in which the expectations and needs of different stakeholders contributed to the identification and screening of several options as well as to the shaping of the tourism mobility service concept. The participation and active collaboration of engineers, marketers, business and innovation consultants and experts from different industries through the innovation process was essential for the generation of an outcome which allowed the responsible commercialization of EVs in the Spanish market. This was achieved by creating a mobility service concept that overcame the previously mentioned barriers for the adoption of EVs. In particular, the adoption of mobility service concept by different stakeholders was due to the

embedding in innovation of values such as *affordability, trust, environmental friendliness, safety, accountability, fun, co-operation* and *profitability*.

4.3 Analysing the case through the Responsible Innovation framework

4.3.1 Analysis of the innovation process and dimensions

The idea for a new mobility service for tourists began with exploring fields or strategic options in which SEAT could create a comprehensive offer of new products and services based on EVs. For doing that, it was adopted a participatory and deliberative approach in which a large number of stakeholders were engaged. Stakeholders included staff from all the relevant areas of the company, a regional driver association, local public administrations, public transport organizations, firms operating in the energy and infrastructure sector as well as suppliers and companies specialized in software and mobile technologies. This approach was adopted so as to learn about stakeholders' capabilities and plans regarding electro-mobility as well as to expand SEAT's knowledge base upon which to generate new ideas. Therefore, stakeholders were invited to participate in two workshops for generating new ideas on products and services revolving around EVs.

In the two workshops organized, a set of methods and tools were used to stimulated deliberations and collective reflection upon a large number of issues related to EVs and urban mobility. These involved discussions, trends and scenario analysis as well as customer empathy maps. The use of these methods and techniques make evident that the innovation process followed several dimensions of RI. In particular, participants were encouraged to discuss and reflect on how different trends could interact and affect to how people will move in future. This led to the development of future urban mobility scenarios. Scenarios helped anticipate relevant changes on values-systems of users regarding mobility[29]. Moreover, participants were invited to collectively discuss about current preferences and concerns of customers regarding urban mobility and EVs. This provided a complex view of customers' values[30] as well as the issues hindering the adoption of electric vehicles. All gained insights were then used to support reflection and the generation of new business ideas that would fit with the prospective scenarios and customers' values and preferences. Hence, by using the mentioned methods and tools the process followed the Anticipation, Participation, Deliberation, and Reflexivity dimensions.

[29] For instance, participants anticipated scenarios in which the value of *ownership* would be less important than it is nowadays. In contrast, participants predicted that in future, values such as *convenience, efficiency, environmental friendliness* and *collaboration* would win social relevance.

[30] For example, participants stressed the importance of the values of *autonomy* regarding mobility. They argue that existing EV technologies limited this value significantly as they only allow travelling 150 km without recharging. Further, participants emphasized the need to reduce EVs prices in order to ensure the *affordability* of those vehicles.

As a result of two workshops, SEAT was able to collect a large number of new ideas. These were analysed and screened to select those ones which would be more aligned with the external environment as well as the organizational strategy regarding EVs. The selected ones were grouped according to common patterns to form several strategic options, which involved products and services for EV owners as well as several mobility services. After reflecting on gained insights into stakeholders[31] and the characteristics, price and limitations of existing EVs technologies, SEAT planned to focus the rest of the project on the creation of mobility services. So, by adopting this decision SEAT was responsive to fundamental customer values regarding mobility, such as *affordability* and *autonomy,* as well as expectations of other stakeholders. Thus, the process adopted made the innovation process follow the Reflexivity, Deliberation and Responsiveness dimensions.

The generation and testing of new mobility service concepts was conducted through a participatory and deliberative approach once again. In this case, the stakeholders involved were staff from all the relevant areas of the company, suppliers as well as potential users and experts from the sectors to which the new services were targeted. The process for concept development involved two workshops. In the first one, a group of employees from the most relevant areas of SEAT were engaged in analysing the attractiveness of targeting different user profiles. Here, the goal was to anticipate which user profiles would enhance the value of *profitability.* To facilitate reflection and decision making, participants were informed about ethnographic and statistical data about several potential users. Based on collective discussions about the different user profiles and their mobility needs, it was decided that the two user profiles that would better ensure the value of *profitability* were*:* city tourists and healthcare professionals. So, the selection of user profiles was enabled by making the innovation process follow the Anticipatory, Reflexivity and Deliberation dimensions.

A second workshop was organized involving marketers, product managers as well as staff from the R&D area at SEAT. This aimed at generating new mobility service concepts addressed to the selected user profiles. During the workshop, participants were requested to discuss on the goals and activities of the two selected users as well as on their unmet needs and unsatisfactory experiences related to their current mobility practices. The analysis of users was performed with the support of different techniques and tools, such as service blueprints (Bitner, Ostrom et al. 2008). Through this deliberative and reflexive approach, participants developed an empathic view of the selected users. Based on this view, participants suggested new ways of satisfying user's needs and values through innovative solutions

[31] During the workshops, SEAT not only generated insights about potential customers but also about the willingness of public administrations to support mobility services based on EVs. In particular, SEAT learned that certain public administrations were keen to promote EVs services as a solution to growing pressure for enhancing air quality in urban areas.

involving EVs. With this approach, in which it is evident that the innovation project followed the Deliberation and Reflexive dimensions, SEAT was able to define two service concepts which embodied a set of values such as *affordability, profitability, autonomy* as well as *environmental friendliness, safety, comfort, fun* and *privacy.* But, how these values were embedded in innovation? For instance, the values of *affordability* and *profitability*, essential for the internal and external acceptability of the outcome, were enabled by designing a pay-per-use business model[32]. This enabled tourists use EVs depending on their needs, without making any investment. On the other hand, the high customer rotation would allow the car maker to generate enough revenues to support financially the service. *Autonomy* was ensured by directing the services to users whose mobility patterns[33] were circumscribed to urban areas. The value of *environmental friendliness* was embodied in the car itself, which enables a zero-emission driving. On the other hand, *safety*[34] was enhanced by including as a part of the vehicle equipment an additional safety system which automatically brakes the vehicle in case of risks of collision with the predecessor vehicle. Moreover, the participants suggested the embedding in the vehicle of a new infotainment system with distinguishing features. This provided tourism information about the surrounding, enabling the embedding in the service of the value of *fun.* On the other hand, the infotainment system was able to inform about parking areas as well as vehicle charging points located nearby to ensure a *comfortable* driving experience. Finally, it was suggested that the infotainment system had to embed encryption capabilities in order to ensure the *privacy* of patient information that the healthcare professional could consult in the vehicle when attending emergency calls.

Before deciding to develop any of the designed concepts, these were tested to assess whether they would address and respond to the relevant values and needs of targeted users and other relevant stakeholders. For testing, SEAT adopted a participatory approach in which several potential customers and experts from the tourism and healthcare industries were engaged through discussions. In those contacts, SEAT used presentations of the mobility concepts to inform stakeholders about the main features of the new services and to prompt discussions about the attractiveness of the services, their shortcomings, as well as on key issues which would need to be considered if the services were going to be further developed and implemented. This participatory and deliberative approach to test the services fostered the generation of new insights about values and needs of customers and other related stakeholders. In particular, through discussions with several actors related to the tourism industry SEAT learned that there existed a growing demand in the tourism industry for *environmental friendly* products

[32] In the case of the health care professionals, *affordability* was ensured by adopting a renting business model.
[33] Both user profiles were selected, among other reasons, because their mobility needs are circumscribed to urban areas. In those areas, it is possible to ensure a sufficient number of recharging points which allow user to charge the car if needed.
[34] Participants anticipated that the rear-end collisions would be the most common in urban areas.

and services. This was due to growing legal and social pressures to reduce the impacts of tourism activities upon the environment. Further, consulted experts anticipated that the proposed mobility service concept for tourists would satisfy an emerging tourist profile characterized by values such as *autonomy*, *individualism* as well as *environmental friendliness* and *always-connected*[35].

On the other hand, discussions with potential customers and experts from the healthcare industry revealed that the service designed by SEAT was not able to respond to user values and needs. In particular, during a meeting with the responsible of vehicles at SAMUR[36] it was learned that the limited autonomy of EVs was incompatible with essential values for the healthcare professionals. From the conversation with the expert, it was deducted that the value of *environmental friendliness* was not the primary one for those professionals. Instead, *care*, *service* and *autonomy* were fundamental and unavoidable values as their duties imply attending all kind of victims, such as those one resulting from car accidents or terrorist attacks[37]. All in all, contacts with stakeholders from the healthcare sector made clear that the requirements and needs of healthcare professionals were not properly meet by the service designed.

The insights gained through testing the concepts were used to support decision making on which service would be further developed and how. After analysing the insights gathered and discussing the alternative ways to overcome the shortcomings detected by the stakeholders, SEAT concluded that EVs were unable to meet the requirements of healthcare professionals. Therefore, it was decided to abandon this concept. On the other hand, feedbacks about the tourism service were considered very positive and revealed new opportunities previously unknown. So, here it is possible to observe how the Anticipatory, Deliberation, Reflexivity and Responsiveness dimensions were present in the identification of new values as well as in the decision-making process to adapt the trajectory of innovation according to the feedback from key stakeholders.

The development of the tourism mobility service concept was done through a participatory and deliberative approach involving the following stakeholders: a tour operator, a company providing services to cruise lines, a software company and SEAT. In particular, the detailed design of the service

[35] According to the consulted experts, there is a new tourist profile who is not interested in hiring existing services based on organized, collective sightseeing tours, because those offerings are not attractive for people who look for more personal experiences based on their likes and preferences.

[36] SAMUR is an organization responsible for emergency medical care located in Madrid

[37] Staff from SAMUR explained that after the terrorist attack of March 2004, in which 192 people were killed and hundreds were injured, all available vehicles were used intensively. In this situation, electric vehicles would not ensure *autonomy* and *care* because the recharging time is, in the best case, of 20 minutes. Under normal conditions, an electric vehicle may need 8 hours to recharge, something totally unacceptable in the circumstances pointed by the SAMUR staff.

and its business model was done through two workshops. In these workshops, participants discussed and reflected on what would be needed to ensure key values for all involved stakeholders, such as quality*, competitiveness* and *profitability*. This was supported through extensive information about customers, competitors' offerings as well as other relevant stakeholders gathered through desk research. Moreover, techniques and tools such as customer journey and service blueprints were deployed to facilitate the anticipation of what customers would do and experience before, during, and after the use of the service and the embedding of key values for this stakeholder in innovation, such as *fun, comfort* and *safety,* to cite a few.

The participatory and anticipatory analysis of the service concept facilitated 1) the identification of multiples issues related to the service; 2) reflection about the potential negative consequences resulting from the use of the EVs as a means to visit the city, and 3) a better understanding of customer values and expectations. Specifically, participants anticipated undesirable situations in which users could be involved, such as car accidents and robberies. On the other hand, certain participants raised concerns about the potential risks of driver distractions due to certain functionalities embedded in the vehicle. Moreover, stakeholders from the tourism industry insisted on the need of reinforcing the value of *environmental friendliness* to respond to key stakeholders' values and expectations. Based on these insights, all participants worked collaboratively in the definition of the necessary resource and processes to ensure customer care as well as a satisfactory and safe customer experience while visiting the city. Hence, the approach adopted made the innovation process follow the Anticipatory, Participatory, Deliberation as well as Reflexivity and Responsiveness dimensions. But, how certain values were taken care and ensured care?

Collective discussions about, reflection on and anticipation of customer experience enabled the definition of new features of the mobility service. For instance, in order to ensure the value of *care*, participants included as part of the service a "customer help-desk service" which would support customers in situations such as accident, robbery, disorientation or car breakdown. This new feature of the service would also ensure the value of *accountability*, as the service provider would assist and be responsible for customers in case of any contingency to happen. Moreover, participants suggested new ways of enhancing the value of *fun* through offering to customers the possibility of searching and purchasing, while using the service, tickets of different cultural and sporting activities available locally. This also enhanced the value of *competitiveness* and *profitability* as it created new revenues streams to support the economic viability of the service. Moreover, the participants responded to the demand of more protection to the environment by proposing that the recharging of vehicle was done exclusively with energy from renewable sources. So, the value of *environmental friendliness* was further supported. Concerns about *safety* were also discussed to ensure that the R&D team in charge of the infotainment

system was aware of the importance of designing a solution that avoided distractions. All in all, the process generated a comprehensive mobility service concept which was approved and adopted by stakeholders for implementation.

Table 9 Summary of how the dimensions were followed through the innovation process

Stages of the innovation process/ Dimensions of RI	Ideation	Concept Design	Concept Testing	Screening of service concepts	Business model design
Anticipation	Anticipation of technological, social, environmental and other trends and how these may affect the values and needs of potential users regarding mobility.	Anticipation of how targeting different user profiles would affect the value of *profitability.*			Anticipation of customer journey and experience. Anticipation of potential risks upon *safety* resulting from the use of certain technologies (e.g. new infotainment system) Anticipation of undesirable situations which could affect negatively on customer experience and therefore, economic sustainability of the new service.
Participation	All relevant areas of the company, driver association, public administration and firms related to urban and electro-mobility.	Staffs from all relevant areas of the company.	Potential users, potential suppliers and partners, and experts from the industries to which the services were targeted.	Staffs from relevant areas of the company.	Staffs from SEAT, tour operator, a company providing services to cruise lines and a software company.

Stages of the innovation process/ Dimensions of RI	Ideation	Concept Design	Concept Testing	Screening of service concepts	Business model design
Deliberation	Understanding how different developments would affect the mobility patterns and preferences of customers. Identification of local barriers for the adoption of EVs.	Discussing the accessibility and size of market depending on different user profiles. Discussing the feasibility of using different technologies. Proposal and evaluation of different features for the new service concepts to satisfy the values and needs of targeted customers.	Discussing with stakeholders the potential benefits resulting from the two service concepts. Identify values for sustainability that were not considered so far. Identify potential barriers for adoption.	Discussions on the feasibility of using different technologies to satisfy the values, needs and expectations of the stakeholders.	Discussions on a large number of issues (risks, customer expectations, resources needed, etc.) related to the new service in order to create a sustainable business model.
Reflexivity	What issues would be relevant for the adoption of EVs? How these issues would affect customer values? What barriers are hindering the adoption of EVs? How to overcome existing barriers for the adoption of EVs?	What needs and values has the service to satisfy? What value proposition would the service have to offer to satisfy the values, needs and expectations of potential users? What technologies would be needed?		Is possible to satisfy needs and expectations of involved stakeholders (users, Top management, etc.) with existing technologies?	What issues could affect negatively customer experience? What features could be enhanced in order to increase the *profitability* of the service? How to ensure the safety of customers? How to increase customer *fun*? What is needed to ensure a *quality* customer service? How would be responsible of what?

Stages of the innovation process/ Dimensions of RI	Ideation	Concept Design	Concept Testing	Screening of service concepts	Business model design
Responsiveness	Decision to pursue business opportunities which ensured key values for the acceptance of EVs, such as *affordability* and *autonomy.*	Changes on vehicle equipment in order to satisfy customer values such as *safety, fun, comfort* and *privacy.*		Decision to develop the mobility service aimed at the tourism industry. Decision to abandon the other service due to the impossibility to cater key customer values with existing technologies.	Changes on the design of infotainment systems in order to ensure the value of *safety.* Changes on the features of the new service in order to enhance *care, fun, profitability* and *environmental friendliness*.

Source: Own elaboration from data collected for analysis of the case

4.3.2 Analysis of the values

The participatory and deliberative approach adopted for carrying out the innovation process enabled car maker and its network the identification and consideration of numerous values for enhancing the desirability and marketability of innovation outcomes. Overall, the analysis of how the innovation process was conducted illustrates that SEAT and its stakeholders cared and ensured care for values that were relevant for users, tour operators, cruise lines, city council, regulators, road users and the car maker. But what values and how they were embedded in innovation through the innovation process?

Two conflicting stakeholders' values seem to be especially considered through the innovation process for enhancing the sustainability of outcomes: the value of *affordability*, key for the adoption of innovation by users, and the value of *profitability*, essential for those which had to support financially the development and implementation of innovation. To overcome this conflict, SEAT and its stakeholders created a new mobility service concept based on a pay-per-use business model. This way of commercializing EVs reduced to the minimum the amount of money that users need to enjoy the EVs. At the same time, this business model promoted high customer turnover, which facilitated the generation of sufficient income to make the business viable.

The engagement with several stakeholders indicated that another essential value for the adoption of EVs was *autonomy.* To ensure this value, SEAT opted to address the service to certain user profiles with specific mobility patterns and needs. As engagement with potential customers and experts revealed, in the case of the tourism service the EVs were able to ensure care of this value. However, in the case of the service for healthcare professionals, EVs were unable to offer the required *autonomy* and, consequently, the concept was abandoned.

SEAT embedded other values in the tourism mobility service concept for enhancing its acceptability, marketability and sustainability. For instance, the integration of a new infotainment system connected to Internet transformed the EVs from being a mobility means to a platform of services. This enabled the embedding of values relevant for the user profile (tourist) such as *fun*, *comfort* and *always-connected*[38]. Further, the new infotainment enabled the generation of new revenue streams through ticket sales. This reinforced the value of *profitability*, essential for the acceptance of the new service by the Top management of all involved companies. On the other hand, the new infotainment system created concerns among stakeholders because it could threaten the user's value of *safety*. This could reduce the acceptability of the service, and therefore its *competitiveness* and *profitability*. So, to enhance the

[38] As pointed out in the analysis of the process and the dimensions for RI, the infotainment systems allowed buying tickets and getting tourism information about the surroundings.

embedding of these values, it was decided to design the infotainment system so that 1) this could not display videos while driving and 2) the driver did not have to look away from the road to enjoy the service. Moreover, the value of *safety* was reinforced by embedding certain Advanced Driver Assistance Systems in the vehicle, which would reduce the risks of suffering a common accident due to driver distraction: rear-end collisions.

The use of electric vehicles to provide the mobility service enabled the embedment of the value of *environmental friendliness* in innovation. SEAT and its stakeholders considered this value as fundamental for enhancing the desirability and *competitiveness* of innovation as it satisfied growing demands from tourists, tour operators and the city council for products and services with less negative impacts in both environment and human health. To embody properly this value in the new service, it was agreed that the source of the energy used to recharge the EVs was critical. Therefore, the charging system of EVs was designed so that renewable energy sources were only used.

Another relevant value considered as important for customers and therefore for the sustainability of the service was *care.* This was embedded in innovation by creating a customer help-desk service. This service was proposed to ensure care of customers and the EVs during the normal development of the service as well as in case of accident, robbery, disorientation or any other contingency. On the other hand, to ensure the *quality* and *efficiency* of the service, a clear assignment of responsibilities among the involved actors was done, according to their experience and capabilities. Thus, the values of *accountability* and *cooperation* were also considered and embedded through the innovation process. These values resulted in the development of *trust* among stakeholders, which contributed positively to the approval of the new concept by the Top management of the involved organizations.

Summarizing, the interactive and iterative nature of the innovation process allowed the design of a new mobility service concept based on EVs. The new concept was based on a value proposition that matched the characteristics of technologies of EVs to the values and needs of all involved stakeholders. This explains the welcome that the concept received from all involved stakeholders. To achieve this matching, SEAT looked for those mobility applications in which the value of *environmental friendliness* was gaining in importance. Then, unlike in traditional ways of commercializing EVs, it was studied the needs and values of all involved stakeholders to ensure the desirability, acceptability and sustainability of the outcome. The stakeholders considered involved tourists, tour operators, cruise lines as well as local public administrations, other drivers and pedestrians, and the car maker. As a result, the responsible commercialization of EVs required the embedding in innovation of a list of values consisting of: *environmental friendliness, affordability, profitability, competitiveness, autonomy, safety, fun, comfort, always-connected, care, accountability, quality, efficiency, cooperation* and *trust.*

Table 10. Values considered with regard to stakeholders affected and/or concerned with innovation

Stakeholder	Value Proposition
Tourist (user)	Environmental friendliness, affordability, autonomy, safety, fun, comfort, always-connected, care, quality, efficiency and trust
Tour operator (partner)	Environmental friendliness, profitability, competitiveness, quality, efficiency, trust, accountability and cooperation
Cruise lines and other actors of the tourism industry (customers)	Environmental friendliness, profitability, quality, and trust
Local public administrations	Environmental friendliness
Other drivers and pedestrians	Safety
Car maker	Profitability, competitiveness, care, accountability, quality, efficiency, cooperation and trust

Source: Own elaboration from data collected for analysis of the case

4.3.3 Analysis of the goals of sustainability

The embedding in innovation of the list of values described above enabled SEAT and its network the generation of an innovation which contributes to environmental and economic sustainability without compromising social sustainability. In fact, the new service aimed to introduce into the market a technology which reduces significantly, if renewable energies are used, the emissions associated with mobility and, therefore, its impacts upon air quality, human health and climate change. Further, thanks to the characteristics of the business model developed, based on sharing vehicles rather than ownership, the service would contribute to a more efficient use of resources and a more environmentally friendly mobility system. The created mobility concept would also contribute to environmental sustainability by increasing the supply of environmentally friendly services in the tourism industry, which needs to reduce significantly its environmental impacts upon socio-ecological systems.

From the economic point of view, the value proposition of the tourism mobility service was designed to make electric vehicles economically accessible to the targeted users. Further, the service was based on a vehicle designed and developed to warrant high levels of *reliability, quality* and *robustness*, what would contribute positively to economic sustainability. On the other hand, the business model adopted enabled producing enough incomes so that the new mobility service could be auto-sufficient from an economic viewpoint, if expenditures required for the design and development of EVs were not considered. The new services contributed with new jobs and creation of wealth. Therefore, it can be considered that the economic sustainability was achieved only partially, as the production of EVs would

still be loss making. In any case, the service would contribute to a more economically-sound introduction of EVs in the market, although the full economic sustainability of producing EVs could only be achieved by increasing considerably the number of units sold.

Last but not less, the new services was designed to facilitate the exploration of cities in an informed, safe and attractive manner, without compromising the way of living or other social aspects of other stakeholders, such as city dwellers. Safety systems were embedded in innovation for ensuring a socially responsible mobility.

Table 11. Contribution of the considered values to the goals of social, economic and environmental sustainability

Values	Dimensions of sustainability		
	Environmental	Economic	Social
Environmental friendliness	X	X	X
Affordability, Profitability and Competitiveness		X	
Autonomy, fun, comfort, always-connected, quality and efficiency,		X	
Safety and care			X
Accountability, cooperation and trust		X	

Source: Own elaboration from data collected for analysis of the case

4.4 Conclusions

How dimensions for RI were followed

The analysis of the case showed that the innovation process involved a set of activities and methods which led the innovation process through the five dimensions for RI. The dimensions for RI were observable at different stages of the process and they contributed in different manners to the identification and consideration of different values necessary for the desirability and sustainability of outcomes. Thus, the Anticipation dimensions was found at different stages, such as ideation, the generation of new mobility concepts and the business model design of the tourism mobility service. The analysis showed that methods such as trend analysis were deployed for prompting reflexivity and deliberations among stakeholders about future technological, economic, social and legal developments and their potential impacts on user values regarding mobility. These enabled innovators the generation of innovative ideas aligned with the certain values that were identified as critical for enhancing the acceptability and sustainability of innovation (e.g. *affordability*, *comfort, environmental friendliness* and *autonomy*). Later, the Anticipation dimension enabled the foreseeing of potential risks resulting from

innovation, such as accidents, robberies or car breakdowns. This prompted actions aimed at handling these risks and to ensure key values for the sustainability of innovation such *safety* or *care.*

The Participation dimension was also observable several times through the innovation process. The analysis of the case revealed that several stakeholders were involved at different stages and with different purposes. At the earliest stage of the process, innovators involved diverse stakeholders to tap into their knowledge and imagination. Reflexivity and stakeholder deliberations about multiples issues were stimulated for discovering user values and environmental issues that would determine the sustainability of any new business idea around EVs. Later, stakeholders were engaged in the innovation process to assess whether the new mobility concepts catered to their values and needs. This participation enabled the generation of new insights about the values and interests of users as well as other relevant stakeholders. Overall, the analysis of the case showed that firms involved potential users and other stakeholders through the innovation process in order to identify values necessary for sustainability as well as to tap into resources needed to satisfy certain values.

A number of activities carried out through the innovation process entailed deliberations among different stakeholders. Deliberations were used to support reflexivity around complex issues. For instance, they were stimulated in the workshops organized for idea generation to create a comprehensive picture about the future mobility scenario and user values regarding urban and electro-mobility. Moreover, deliberations were deployed in the design of the business model to explore how to deal with the potential risks resulting from innovation, to enhance the economic and environmental sustainability of outcomes as well as to share responsibilities among stakeholders in order to take care of customers and vehicles. Deliberations were also utilized for gaining new insights about stakeholder values and interests during the activities aimed at testing the new concepts.

It was also found that reflexivity was stimulated in several activities through the innovation process. This enabled innovators and their stakeholders to develop new understandings about the values and issues which needed to be considered to enhance the acceptability, desirability and sustainability of new ideas and concepts. Thus, the collective analysis of a wide range of trends in the first workshops helped understand how these would modify the value-systems of users. These insights were then used to prompt new ideas which would fit with the prospective context. In a similar vein, innovators engaged in collective reflections about the needs and values of tourists and other stakeholders in order to facilitate the design of new mobility concepts whose features reflected the values and expectations necessary for their acceptability, desirability and sustainability. More importantly, reflections about technologies used and their potential consequences led to design changes to ensure a safe driving experience.

In the analysis of the innovation process was also evident that the orientation of the search for new business opportunities as well as the design and development of new mobility service concepts responded to the values, needs and expectations identified through the different activities. Responsiveness was supported by the wide participation of stakeholders through the innovation process. Potential users, tour operators, cruise lines, infrastructure managers, health care professionals and other stakeholders were involved in different activities to understand their values and expectations with regard to mobility. The analysis showed that their inputs and concerns were considered in decision making processes and shaped the trajectory of innovation. For instance, one mobility service concept was abandoned after considering that the characteristics of EVs were unable to satisfy essential values for health care professionals, such as *autonomy* and *service*. On the other hand, innovators fostered important changes in the car equipment (e.g. in the infotainment system) in order to cater to the values and needs of tourists and other stakeholders, such as tour operators.

Values

The analysis of the case exposed that innovators cared and ensured cared for a number of values for achieving that the resulting outcomes were acceptable and desirable for all involved stakeholders. To achieve that result, the new mobility service was designed so that it embodied several values (e.g. *fun, safety, comfort* and *environmental friendliness*) which transformed the EVs in a platform for enjoying in an affordable, safe and clean manner a city sightseeing tour. This made the use of EVs attractive from the user perspective. Further, the resulting innovation catered to the needs and interests of affected stakeholders, such as tour operators, cruise lines and city councils. This was achieved by embedding in innovation values such as *profitability, quality, care, competitiveness* and *environmental friendliness*. All in all, the participatory and deliberative approach adopted through the innovation process enabled the generation of a mobility service concept based on EVs which would overcome the shortcomings of previous attempt to commercialize this technology. This was achieved by embodying in innovation the values of all involved stakeholders, including: *environmental friendliness, affordability, profitability, competitiveness, autonomy, safety, fun, comfort, always-connected, care, accountability, quality, efficiency, cooperation* and *trust.*

Ensuring the goals of social, environmental and economic sustainability

The analysis of the case suggested that the features and characteristics of innovation would bring new benefits from economic and environmental perspectives, without imposing new burdens upon social aspects of sustainability. Therefore, it could be concluded that innovation ensured the goals of social, environmental and economic sustainability.

5 The introduction of new Advanced Driver Assistance Systems

5.1 Introduction

Drivers are enabled by bringing out new innovations to assist them for enhanced safety and better control in cars. Such new emerging innovations become facts for debate for their impacts and the way they are introduced (Planing 2014). This raises the question about how these new innovations would become more responsible and accountable for users, society and environment. Therefore, this chapter focuses on an innovation process aimed at exploring and enabling its introduction in vehicles as Advanced Driver Assistance Systems (ADASs). This case is being considered an instance of the responsible innovation approach.

The selected case describes the process for adoption and commercialization of three new ADASs. The innovation process started in 2012 and ended with the implementation of the ADASs in several vehicles in 2015. In this chapter, it will be explored how the (ADAS) innovation process was organised and executed, and how different dimensions of the responsible innovation approach were followed (Section 5.3). Then, Section 5.3.3 will be devoted to analyse what and how values were considered through the innovation process to enhance the marketability, desirability and sustainability of outcomes. In Section 5.3.3, it will be evaluated whether the outcome contributed to social, economic and environmental sustainability as final goal of a responsible innovation. The final section (Section 5.4) will focus on conclusions. Before delving into de analysis of the case, Section 5.2 presents briefly a description of the background of the case as well as brief description of innovation outcomes.

5.2 Background and description of the case

In 2005, road accidents accounted for 41.600 deaths and more than 1.7 million injured (EC 2006). The vast majority of accidents are explained or due to human failure (93,5%), while technical defects of vehicles represent only 0,7% of accidents (Schwarz 2006). On the other hand, safety is one of the three most important issues that determines customer's buying decisions of vehicles (KPMG 2015). These figures explain, at least in part, the interests and efforts of the car industry for the development of new technologies that increase the safety of vehicles by assisting drivers in different driving tasks. Among those technologies, Advanced Driver Assistance Systems (ADASs) are the fastest growing safety applications. ADASs consist of a combination of sensors, cameras and displays which enhance driver visibility and also support drivers in potentially hazardous situations by, for instance, taking control of the vehicle to avoid or reduce the consequences of an accident (e.g. it may brake the vehicle automatically to avoid a rear-end collision) (Intersil 2015).

The present chapter analyses an innovation process aimed at the identification, selection and adoption of a set of ADASs[39] to improve vehicle safety. The process was conducted by SEAT and its network. SEAT, as part of a group of companies -the Volkswagen Group[40] (VW group) - did not design any ADAS. Therefore, in this case the processes performed by other companies (car makers and/or suppliers) for designing, developing and validating for the first time the ADASs considered in this case are not analysed. Instead, the case depicts how SEAT selected ADASs, from a pull of systems available within the VW group, developed and integrated them into their vehicles to enhance their safety, marketability and competitiveness.

The innovation process for bringing out new ADASs entailed the participation of different stakeholders: from all the relevant areas of the car maker, the VW group and suppliers to potential customers as well as homologation entities. During the process, multiple issues were considered in order to ensure the responsible adoption and deployment of ADASs. As a result, three ADASs were selected and implemented, which enhanced comfort and safety in different ways. So, one of the selected systems is aimed at increasing the comfort of parking manoeuvres. The second provides information to drivers in potentially risky situations so that they can manoeuvre to avoid or reduce the odds of suffering an accident. The last ADAS involves different technologies which take control of the vehicle in a risky situation in order to avoid an accident, or to reduce its consequences upon other road users.

The process for selection and implementation of the three ADASs was the same for all three cases. This was done according to the values, expectations and requirements of different stakeholders, from users, shareholders, the car maker and regulators, for the responsible introduction of ADASs in the market. As a result, the process allowed the implementation of ADASs which embedded in vehicles a set of values, including such as *safety, affordability*, *effectiveness, cost effectiveness, competitiveness, comfort, responsibility, trust, legality, environmental protection, recyclability, reliability, efficiency, robustness and quality*.

[39] For confidentiality reasons, it is not possible to reveal the names of the considered systems. In any case, it is possible to indicate that the selected systems encompassed new functionalities to facilitate parking maneuvers, to control the vehicle speed, to avoid collisions, to reduce the impacts in case of accident as well as to reduce the odds of suffering accidents due to driver fatigue or distraction.

[40] Within the VW group, the different brands share vehicle systems, components and parts in order to reduce design and development costs and to increase the competitiveness of their products. Shared systems, components and parts are usually designed and developed by one brand of the VW group according to the needs of all the different brands. Then, they become available for all brands which would adopt and adapt them depending on the characteristics of the vehicle and the targeted users.

5.3 Analysing the case through the Responsible Innovation Framework

5.3.1 Analysis of the innovation process and dimensions

The idea for exploring new ADASs for new variants of cars began with informal deliberations among the staff from the Marketing department and engineers from the R&D area. These groups anticipated that ADASs would have an important effect on the value of *safety* as well as on the *competitiveness* of new vehicles in the coming years. These conclusions resulted after exchanging viewpoints on different environmental issues, such as the growing importance that Euro NCAP[41] was given to ADAS in its safety assessments, the results of market research[42] studies, which showed growing expectations from users for vehicle technologies which enhance safety, and competitors' analysis which indicated that competitors were responding fast by introducing new ADASs into the market. This anticipatory and deliberative exercise led Marketing and R&D staff to propose the organization of a process aimed at identifying and proposing to the Top Management suitable ADASs for enhancing the *safety* and *competitiveness* of SEAT vehicles.

The process for identification and selection of ADASs was structured through a set of participatory and deliberative activities in which stakeholders from all the relevant areas of the company as well as their networks were engaged. This approach was adopted to ensure that all technical, manufacturing, financial, marketing and other key issues necessary for the successful adoption and commercialization of ADASs were considered from the outset of the process. As a first step, several preparatory working discussions took place to define a suitable list of criteria for the selection of ADASs. Deliberations and collective reflections were deployed by stakeholders to exchange viewpoints and to decide what criteria would be the most suitable according to the values of targeted customer and the firm strategy. As a result, participants agreed on a set of criteria that were expected to favour the acceptability and desirability of the selected ADASs. These would reflect key values for customers as well as for Top management, such as *affordability, comfort* and *safety* as well as *cost-effectiveness* and *competitiveness.*

Once the criteria were agreed, it was initiated a process for assessing a long list of ADASs available within the VW group to select those which would be, at least *a priori*, the most suitable for the targeted

[41] Euro NCAP (European New Car Assessment Programme) is an European car safety performance assessment programme supported by the European Commission, seven European governments as well as motoring and consumer organizations located at different EU country. Euro NCAP was created to stimulate the research and development of safer vehicles (www.euroncap.com)

[42] SEAT continuously engages with potential customers in order to anticipate their values and expectations regarding vehicles. This is done through a large number of qualitative and quantitative market research methods, such as focus group, email and phone surveys as well as interviews and contextual observations. Information resulting from market research is then used to support the design and development process of a new vehicle.

users and their mobility patterns. The assessment and selection of the ADAS was done through a workshop in which it is possible to observe features of the Anticipation, Participation, Deliberation and Reflexivity dimensions. The participatory approach is clearly reflected in the fact that all areas of the company[43] and key stakeholders from the VW group were engaged. Again, this approach was adopted to ensure that the values and interests of all stakeholders relevant for the adoption of innovation were considered through the selection process. On the other hand, in the workshop several activities were deployed which stimulated a reflexive and deliberative decision-making process that ensured responsiveness to the values of key stakeholders. In particular, reflexivity and responsiveness were encouraged by providing participants information about current and prospective issues which could affect the desirability, marketability and therefore, the sustainability of innovation. Participants were informed about the features of several ADASs; the socio-economic characteristics, values and preferences of targeted customers; results from trends analysis studies which indicated how mobility patterns and customers preferences would evolve in future[44], as well as the competitive landscape. Further, participants were informed about which ADAS were considered by Euro NCAP in its safety assessment, to stress what systems would be the most relevant from the *safety* and *competitiveness* perspectives. Based on all this information, participants were asked to discuss and select the most suitable ADASs to satisfy the values and interests of customers as well as the own company.

The selected systems were then presented to the Top Management in a second workshop organized for deciding which ADAS would be worthy to assess in-depth[45]. In this workshop, test drives of vehicles with the pre-selected ADAS were conducted to anticipate whether its functionalities and benefits would fit with the targeted customers. Potential customers were not involved in these tests. Instead, senior managers drove and experienced the different ADASs. After every test, they were asked about their opinions on whether the ADASs would fit with the targeted user profile or not. Opinions from each manager were shared with the rest in order to enrich the decision-making process. As a result of this process the Top Management approved a shorter list of ADAS[46] that, according to their views, reflected

[43] Stakeholders included staff from Marketing, Product Management, Sales, Quality, Manufacturing and R&D.

[44] This information is collected regularly by the Marketing Department and the VW group through different foresight and market research methods. Thus, interviews with experts from different fields, media content analysis and desk research are used to identify technological, social, economic, political and environmental trends as well as the future impacts that those trends may have in customer values and preferences. On the other hand, values and preferences of different socio-economic groups are gathered through ethnographic research, in which social scientists interview and observe people in their context. Moreover, focus groups with potential customers as well as phone and email surveys are used to assess the desirability of certain systems or functionalities.

[45] In depth-assessments are carried out in order to provide key information to Top management so that they can decide whether to adopt and implement the system or not.

[46] For confidentiality reasons, it is not possible to reveal the names of all reviewed systems. In any case, it is possible to indicate that the selected systems encompassed new functionalities to facilitate parking maneuvers, to

better the values of customer target as well as the values that the company wanted to embody in its vehicles.

The in-depth assessment of the selected ADAS was conducted through a process in which all relevant areas of the company and their networks were engaged. The process aimed to anticipate and assess the prospective market, technical, manufacturing and financial consequences of embedding each selected ADAS in SEAT vehicles. This was conducted by a cross-functional team in order to ensure that all relevant issues for the development, marketability and manufacturability were considered through the process. As a result, the team elaborated the business case for each system and recommended to Top management the commercialization of three ADASs, as they were the ones which better responded to the values of *safety, affordability*, *competitiveness, comfort* and *cost-effectiveness*. So, the process developed for selecting and assessing which ADASs to adopt and commercialize shows evidences of the Anticipation, Participation[47], Deliberation, Reflexivity and Responsiveness dimensions.

The R&D group of SEAT and its network were responsible for the technical development of the ADASs. This was conducted through an iterative process in which different activities and methods were deployed in order to ensure that the adopted ADASs would fulfil a wide range of economic, environmental, technical, safety as well as legal and quality requirements. These requirements were set to support the development of systems so that these minimise potential negative impacts upon human health, the environment and upon the financial performance of the company. Therefore, requirements reflected and ensured care of a set of values required for the acceptability, desirability and sustainability of the new vehicle safety systems, such as *safety, efficiency, cost effectiveness, environmental protection, recyclability, robustness, reliability, legality* and *quality.* Further, during the development stage engineers and developers subjected the different components of the new ADASs to fatigue, functional[48] and electromagnetic compatibility tests to assess whether they would ensure the expected levels of *reliability*, *quality* and *safety*. Further, they conducted driving tests in the Polar Regions and deserted areas to anticipate and assess whether the systems would ensure a proper functioning in all kind of weather conditions. On the other hand, driving tests were performed in real traffic situations to ensure that the systems functioned *effectively* and provided the level of *safety, reliability* and *robustness*

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control the vehicle speed, to avoid collisions, to reduce the impacts in case of accident as well as to reduce the odds of suffering accidents due to driver fatigue or distraction.

[47] Although potential customers were not involved in the selection process, it is considered a participatory process as the process involved members of the relevant areas of the company. This includes members from the Marketing department which assessed the different systems according to the knowledge they had generated about the values, needs and expectations of potential customers.

[48] Components are subjected to Hardware-In the Loop tests to simulate and assess their functioning in interacting with other vehicle systems.

anticipated in the design and development processes. So, during the process of technical development it is possible to observe how the innovation process followed successfully the Anticipation, Reflexivity and Responsiveness dimensions.

During the development of the vehicles in which the new ADASs were going to be embedded, potential customers were involved to generate knowledge about their values, likes and preferences with regard to these and other new systems. Thus, marketers engaged with potential customers through reflexive and deliberation methods, such as focus group, to discuss about the desirability of the new functionalities, their potential benefits and the customer willingness to pay for them. Thus, marketers were able to gather key information which enabled to assess whether the prospective systems would cater to customer values and expectations. Feedbacks from potential customers were shared with Top management and other internal stakeholders in order to support decision making processes related to strategies on how to ensure the marketability of the new systems. So, here it is possible to observe evidence that the process followed the Participation, Deliberation and Reflexivity dimensions.

Table 12 Summary of how the dimensions were followed through the innovation process

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Screening and pre-selection of systems	Selection of systems	Technical development	Voice of the Customer[49]
Anticipation	Anticipation of the positive impacts of new ADASs on values such as *safety* and *competitiveness.*	Analysis of social, cultural, technological and other trends expected to have an impact on values and purchasing preferences of customers. Anticipation of customer experience in order to assess if the systems would fulfil their needs and expectations	Anticipation of the impacts of the pre-selected ADASs on values such as *affordability, cost-effectiveness* and *competitiveness.*	Anticipation of potential failure modes in order to ensure the development and commercialization of *safe* and *reliable* systems Establishment of environmental and technical requirements to avoid negative impacts on human health and environment in the future. Evaluation in an anticipatory manner of the performance of innovation under different conditions in order to assess whether they would ensure throughout its life-cycle values such as *safety, robustness, reliability* and *quality*.	Anticipation of changes on customer values and purchasing preferences according to social, technological, ecological, political and other developments.
Participation		Representatives from all the relevant areas of the company Experts on ADASs from the VW group Top management	All relevant areas of the company. Top management	Different areas of SEAT, including R&D and the prototyping department. Experts on the ADASs from the VW group. Suppliers	Potential customers Marketers Different areas of SEAT Experts from the VW group Experts on technological, social, economic, environmental and other issues

[49] This is a process carried out along the innovation process. According to the stage, potential customers were engaged for different purposes (from developing knowledge about their values and expectations to assessing particular designs and equipment)

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Screening and pre-selection of systems	Selection of systems	Technical development	Voice of the Customer[49]
Deliberation	Discussions about environmental issues which could be relevant for the *competitiveness* of SEAT vehicles.	Discussions on the values which needed to be considered for the pre-selection of ADASs. Discussions about the pros and cons of adopting certain ADASs according to the criteria set.			Dialogues with potential customers in order to understand their preferences, value systems and expectations. Dialogues with potential customers in order to assess whether the selected ADASs would cater to their needs and expectations.
Reflexivity		What criteria would enhance the sustainability of ADASs? What ADASs would be the most convenient according to current and prospective customer values, competitive landscape and features and performance of different systems? Would the pre-selected ADASs cater to customer needs and values?		Is the prospective innovation working as expected? What issues could affect negatively the *safety, reliability, robustness, quality,…*of innovation? Does innovation provide the expected levels of *safety, reliability, robustness* and/or *quality*?	What values would it determine the purchasing preferences of potential customers in future? What systems or features would it be the most demanded according to prospective customer values? What features of the ADASs do potential customers value? What features of the ADASs do potential customers dislike? How much are potential customers willing to pay? Do they expect ADASs to be optional equipment or series equipment?

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Screening and pre-selection of systems	Selection of systems	Technical development	Voice of the Customer[49]
Responsiveness		Pre-selection of systems according to user values, such as *safety, comfort* and *affordability.*	Adoption of systems which would ensure key values for stakeholders, such as *safety, affordability, comfort competitiveness* and *cost-effectiveness.*	Consideration of certain *environmental* and *safety* requirements to enhance the sustainability of outcomes Deployment of methods to adjust the systems involved in order to ensure the values of *quality, reliability, safety, effectiveness* and *robustness*	

Source: Own elaboration from data collected for analysis of the case

5.3.2 Analysis of the values

During the innovation process for adoption and commercialization of the three ADASs, innovators ensured care of a set of values in order to warrant their responsible introduction into the market. At the early stage, innovators considered ADASs as an effective technical solution in order to embed *safety* in vehicles. Then, innovators screened available systems according to a set of issues, such as the purchasing power of targeted customers, customer's mobility patterns, the safety performance of alternative options and whether competitors were selling a particular system or not. In this way, innovators shaped the trajectory of innovation towards those systems which would ensure care of other values necessary for sustainability according to the context, such as *affordability, effectiveness, cost-effectiveness* and *competitiveness*.

During the development process the activities and methods deployed enabled ensuring care of other values required for the ethical acceptability, social desirability and sustainability of outcomes. Specifically, the car maker and its stakeholders deployed a process aimed at embedding in innovation values such as of *responsibility* and *trust*. *Responsibility* was ensured in different ways. On the one hand, innovators deployed certain methods, such as Failure Modes and Effects Analysis (FMEA), to facilitate the development of *robust, reliable* and *safe* systems. Further, they performed an array of laboratory and driving tests in order to assess, before commercialization, that the resulting systems effectively embody the values of *robustness, reliability, quality* and *safety* of vehicle occupants and other road users. On the other hand, *responsibility* was further embedded through the innovation process by imposing certain requirements for reducing potential negative impacts upon human health and ecological systems of innovation outcomes. Thus, *environmental protection* was considered by imposing requirements such as: prohibition of using toxic materials; the obligation to mark the plastic materials used to facilitate their separation and *recyclability*, and the obligation to design and develop the system so this can be recycled at 95% of its weight. Further, *responsibility* was also ensured by sharing with treatment operators all information regarding the material used for the manufacturing of the new systems so that they could be treated effectively at their end-of-life stage.

With regard to the value of *trust*, this was embedded in the system by subjecting the different systems to the evaluation of independent entities. Thus homologation entities verified the fulfilment of the different norms and regulations, and therefore, the *legality* of the new innovations.

Summarizing, the list of values that the car maker and its network considered for the adoption and commercialization of the two new ADAs includes: *safety, comfort, affordability, competitiveness, responsibility, trust, legality, reliability, robustness, quality, effectiveness, efficiency, cost-effectiveness, recyclability* and *environmental protection*.

Table 13 Values considered with regard to stakeholders affected and/or concerned with innovation

Stakeholder	Value Proposition
Driver	Safety, comfort, affordability, trust, legality, reliability, robustness, quality, effectiveness and efficiency
Other road users	Safety
Car maker	Competitiveness, responsibility, trust, legality and cost-effectiveness
Regulators	Safety, responsibility, legality, trust, reliability, robustness, quality, effectiveness, efficiency, recyclability and environmental-protection
Consumer protection associations	Safety, responsibility, trust, legality and cost-effectiveness

Source: Own elaboration from data collected for analysis of the case

5.3.3 Analysis of the goals of sustainability

To what extent is the innovation outcome contributing at social, economic and environmental sustainability? The case illustrates an innovation process whose outcomes enhanced the social sustainability of road mobility through improving the safety of vehicles. In particular, two selected and implemented ADASs contributed to one of the main goals of European societies for promoting a sustainable mobility: to reduce the number of car accidents and/or their impacts upon human health (EC 2001). The embedment in the vehicle of these new ADASs can then be considered as a positive step toward reducing one of the causes of death that only in Europe is responsible for more than 25.000 casualties per year (EC 2015). On the other hand, the social desirability of these systems is reflected in the growing demands that they have experienced in the last years, and in the importance that certain institutions promoting a safer mobility, such as Euro NCAP, give them in rating the safety of vehicles.

The ways how the ADASs were selected, developed and implemented contribute to economic sustainability in two ways. First, all ADAS systems were selected and developed to ensure values such as *affordability*¸ *robustness*, *quality* and *efficiency*. This allowed that thousands of people can adopt and use these systems for a safer driving. On the other hand, the sale of the new systems improved the profitability per vehicle sold. This contributes to the economic sustainability of the car maker, which plays a fundamental role in the regional economic system and the generation of jobs.

With regard to the environmental sustainability, the systems developed were not aimed at improving the environmental performance of vehicles. In any case, the actions performed during the innovation process were addressed to minimize the environmental impacts of the different materials involved as well as the overall environmental performance of the vehicle (e.g. by minimizing weight and electric

consumption and thus the overall vehicle consumption). Furthermore, the ADAS were designed and developed to ensure 1) a high degree of protection of human health as well as 2) their recyclability and safe treatment at the End-of-Life stage of vehicles. Other criteria for enhancing the environmental sustainability of outcomes were not considered. Thus, there is no evidence that the selection of materials were done to minimise as much as possible the environmental impacts of innovation. Instead, materials were selected to ensure other values such as *cost-effectiveness*, *quality, reliability, robustness, recyclability* and *safety*.

Table 14. Contribution of the considered values to the goals of social, economic and environmental sustainability

Values	Dimensions of sustainability		
	Environmental	Economic	Social
Safety	X	X	X
Affordability, cost-effectiveness, competitiveness		X	
Reliability, robustness, quality, efficiency, effectiveness	X	X	X
Responsibility	X	X	X
Trust		X	
Recyclability and environmental protection	X		

Source: Own elaboration from data collected for analysis of the case

5.4 Conclusions

How dimensions for RI were followed

This chapter has shown that the methods and activities deployed throughout the innovation process enabled innovators to select, develop and commercialize three ADASs according to the values and expectations of a group of stakeholders, including drivers, other road users, regulators, consumer protection associations and treatment operators. Further, it was found that the methods and activities that innovators used through the innovation process permitted the observation of the five dimensions of RI. Dimensions contributed in several manners to identify and embed certain values in innovation. In particular, there were found evidence of the Anticipation dimension in several activities, such as opportunity identification, screening and pre-selection of available systems, identification and assessment of the potential consequences of adopting and commercializing different ADASs and, especially, in the technical development of the selected ADASs. Thus, the anticipation of the potential consequences upon values such as *safety,* resulting from the adoption of certain technologies,

prompted efforts to adopt those technologies. On the other hand, innovators deployed risk assessment methods to anticipate what events could suppose a risk upon the functioning of the system and, consequently, upon drivers and other road users. The results of this anticipatory exercise were used to ensure key values for social and economic sustainability, such as *reliability, safety* and *quality*. Moreover, the anticipation of how ADAS would perform under different conditions were used as a mechanism to assess whether innovation would ensure care of values such as *safety, reliability, robustness, effectiveness* and *quality*, and to iterate if those values were not properly embedded in innovation.

With regard to Participation dimensions, it was found that through the innovation process many activities were conducted with the participation of representatives from the most relevant areas of the company as well as other actors from their networks (e.g. experts from the VW group and potential customers). The engagement of representatives of the most relevant areas of the company enabled the consideration from the outset of the process of the different interests, values and perspectives necessary for enhancing the sustainability of innovation. On the other hand, it was found that users were involved in the process through traditional marketing methods, such as focus groups, for generating key knowledge about their values and expectations with regard to prospective vehicles and their equipment, including ADASs. This knowledge was then used by marketers and other staff from SEAT to support decision-making process. Here, the question arises whether a more active participation of potential users through the innovation process would not have contributed to a different selection of ADASs, maybe more aligned with their values and needs.

To support different activities, such as screening of ADASs, it was found that deliberations played a relevant role. Thus, deliberations were used for handling complex innovation related issues, such as deciding which criteria would be the most suitable for screening ADASs or exchanging of viewpoints about the pros and cons of adopting alternative systems. Deliberations were also used to engage with potential users in order to generate knowledge about their values and preferences with regards to the prospective innovation.

It was found that through the innovation process, engineers, marketers, product managers and other stakeholders reflected collectively on a large number of environmental cues in order to support decision making process about which ADASs would be the most suitable for adoption. This reflexive exercise helped those involved in the innovation process to understand which values and issues needed to be considered and to direct the trajectory of innovation accordingly. Further, the technical development of the adopted ADASs could be considered as a reflexive process in itself. Thus, in order to ensure that innovation outcomes would reflect essential values for their sustainability, such as *reliability, robustness,*

safety and *quality*, ADASs were subjected to multiple tests and repeatedly assessed to support decision making about their development and implementation.

The analysis also showed that innovators were responsive to the values and interests of several stakeholders in order to ensure the sustainability of outcomes. Thus, SEAT was responsive to user demands for safer vehicles since the early stages of the innovation process. Further, knowledge about potential customers helped shape innovation so that outcomes responded to customer values essential for desirability and sustainability, such as *affordability*. It was also found that SEAT and its network were responsive to legal and societal demands for a more environmentally sustainable mobility. This was achieved by imposing a number of requirements for product development. These enhanced the sustainability of innovation by ensuring care of values such as *safety, reliability* and *effectiveness* as well as *recyclability.*

Values

In the innovation process for selecting and commercializing new ADASs, engineers, marketers, product managers and other stakeholders performed a set of activities which allowed the identification and caring of essential values for enhancing the marketability, social acceptance and sustainability of the new safety systems. Thus, the efforts for enhancing the embedment of the value of *safety* in vehicles were modulated by other values that stakeholders considered fundamental for adoption, such as *affordability* and *competitiveness.* Further, the responsible marketing of the new ADASs required addressing other values essential for the ethical acceptability and social desirability of outcomes, such as *quality*, *reliability, robustness, recyclability, environmental protection* and *effectiveness*. All these values were considered through the process according to regulations, industry standards and company's product policies for a safe commercialization of vehicle safety systems.

Ensuring the goals of social, environmental and economic sustainability

The analysis of the case indicated that the new ADASs would support the goals of social and economic sustainability by enhancing the *safety* of vehicles and road systems in an economically affordable and profitable manner. With regard to the environmental dimension of sustainability, the new systems were designed and developed considering essential requirements for the protection of human health and ecological systems, such as *safety* of use, *recyclability* and use of non-toxic materials. Other requirements for a more comprehensive protection of ecological systems, such as the use of renewable materials, were not applied as they would compromise other values for sustainability, such as *reliability*, *robustness, quality* or *cost-effectiveness*. So, this case may not be the best example of the responsible innovation approach, although for the purposes of this research would suffice as provided interesting

insights about how certain values for sustainability were considered and embedding in innovation values for social and economic sustainability.

6 The Multi-collision Brake System

6.1 Introduction

Road accidents are a topic of political and social concern due to the terrible consequences that they have in terms of casualties and injured people as well as economic losses every year. Reducing the number and consequences of road accidents is a shared responsibility among all involved actors and an essential step to achieve a more sustainable road transportation system. But how involved actors innovate to increase the vehicle safety so as to reduce the number and consequences of accidents? This case has been selected for being considered an evidence for responsible innovation approach. It focuses on an innovation process aimed at creating, developing and commercializing a new safety system called Multi-Collision Brake (MCB). The innovation process began in 2011 and the new system was deployed as part of new vehicles[50] in 2012.

As in previous cases, this chapter will begin with a brief description of the background and the innovation outcomes (Section 6.2). Next section will be focused on analysing how the innovation was developed and how the different dimensions for RI were followed (Section 6.3.1). In Section 6.3.2, it will be analysed what and how certain values were considered through the innovation process. Then, it will be evaluated whether the innovation outcomes contributed to the goals of social, economic and environmental sustainability (Section 6.3.3). The chapter closes with a section on the conclusions that could be drawn from the analysis of the case (Section 6.4).

6.2 Description of the case

Car accidents were responsible for more than 25.000 casualties in 2014 in Europe (EC 2015). The enhancement of road safety goes beyond the responsibility of car makers but it requires the coordinated actions of all involved stakeholders in order to tackle this complex and painful issue. In the last decades, different stakeholders concerned with the safety of the road transport system have engaged in several projects across Europe to investigate how safety could be enhanced. Among these initiatives, a project called GIDAS[51] was launched in 1999 in Germany. This project aims to improve road

[50] The VW Golf (generation VII) and the SEAT Leon (generation III) are some models which incorporate this system.
[51] GIDAS stands for German In-Depth Accident Survey. It is a joint venture created in 1999 and sponsored by the Federal Highway Research Institute (BASt) and the Automotive Research Association (FAT). Both institutions are located in Germany. The BASt is the practice-oriented, technical-scientific research institute of the German Government in the field of road engineering (www.bast.de). On the other hand, FAT unites all German passenger and commercial vehicle manufacturers as well as numerous suppliers for the purpose of carrying out pre-

safety by generating and sharing knowledge among stakeholders about the causes and consequences of road accidents. In 2011, the analysis performed by a research group at the Volkswagen group (VW group) of the road accident database generated by GIDAS provided evidence over the tragic consequences of a particular type of accident: the lateral collision against the guardrail. Based on these findings, Volkswagen and its network jointly explored for the possibilities of reducing the consequences of this particular type of accident. As a result of the process, a new functionality was proposed, developed, tested and implemented in the vehicles produced by the VW group. This new functionality is called Multi-Collision Brake (MCB). The MCB is a safety system that aims to reduce the consequences of accidents by reducing the odds that crashed vehicles invade the opposite lane. The MCB works as follows: in the case of a lateral collision with the guardrail, the crash recognition system detects this situation and triggers automatic controlled braking to slow down and stop the vehicle. To ensure that the driver can keep the control of the vehicle at any time, the system allows the driver to control the vehicle even if the MCB is acting. Thus, the driver can stop the MCB at any time by accelerating or braking even more strongly (VW 2015).

The MCB was created through an iterative and interactive process in which the participation of different stakeholders resulted essential in the generation of a safe, viable and economically-sound outcome. The participation of engineers, experts on vehicle and road safety and human behaviour as well as marketer and other stakeholders was ensured in order to generate key knowledge for the responsible design and development of new safety systems. As a result, the innovation process provided a new functionality that ensured care of values such as *safety, reliability, robustness, autonomy, profitability, affordability, cost-effectiveness, competitiveness, legality, responsibility* and *trust.*

6.3 Analysing the case through the Responsible Innovation Framework

6.3.1 Analysis of the innovation process and dimensions

The participation of the Volkswagen Group in the GIDAS project enabled the identification of a new opportunity for further enhancing the value of *safety* in vehicles and road systems. This participation allowed the team responsible for road accident in-depth studies (hereafter, the RAIDS team) at the VW group to access to, and analyse a large number of road accident data, which would not be feasible to collect otherwise. Reflections on statistical analysis of these data permitted the RAIDS team to conclude that the invasion of the opposite lane by a vehicle after a lateral collision with the guardrail increased significantly the negative impacts of car accidents. This led this team to predict that if it was possible to

competitive joint research (www.vda.de). GIDAS involves other stakeholders affected and concerned with road safety, including people who had suffered an accident, medical institutions and research centres.

prevent vehicles from invading the opposite lane, the consequences of car accidents would decrease notably. Therefore, they informed about their findings to the group of experts on vehicle safety systems at the VW group to explore for potential technical solutions. So far, it is possible to observe through the process evidences of the Participation, Reflexivity and Anticipation dimensions.

The search for technical solutions for preventing vehicles from invading the opposite lane was done through deliberations and collective reflections among the group of experts on safety systems working at different departments and companies of the VW group. Deliberations were used to explore the feasibility, *cost-effectiveness* and technical implications of different alternatives for reducing the vehicle speed in case of a lateral collision. Experts believed that some sensors installed on board could provide a trigger signal to the braking system in case of a lateral collision to occur, but doubts raised about the *effectiveness* and *reliability* of the on board systems for distinguishing this type of collisions from others. Hence, it was agreed to conduct a series of laboratory tests to assess whether the systems installed on a vehicle would be able to identify lateral collisions in a consistent and robust manner, before exploring more complex technical alternatives.

The laboratory tests confirmed that on board systems would ensure values such as *reliability* and *effectiveness* in providing a trigger signal in case of lateral collisions. This signal would enable the automatic activation of the braking system to reduce the speed of vehicle and thus the odds of invading the opposite lane. The results of the laboratory tests were then shared with the rest of internal stakeholders[52] who had essential knowledge and resources for assessing the potential marketability, development and sustainability of the new safety concept. The involved stakeholders anticipated the potential consequences resulting from the development and commercialization of the new safety concept and evaluated whether these would ensure care of values such as *affordability* and *cost-effectiveness,* essential for the acceptance of innovation by customers and Top management. So, in the process of generating, testing and assessing new ideas, the Deliberation, Anticipatory and Responsiveness dimensions were followed.

The design and development of the MCB was done through an iterative and deliberative process articulated around certain standards[53]. These standards were created and adopted by the car industry to facilitate the commercialization of vehicle safety systems so that they embody key values for their safe adoption by society, such as *effectiveness*, *error robustness, reliability, responsibility, autonomy* and *safety*. The process involved among other activities the anticipation and categorization of all potential

[52] Stakeholders included experts from the most relevant areas of the company, such as marketing, finance, quality, manufacturing and purchasing departments.
[53] The specific safety standard applied within the car industry related to safety systems is the ISO 26262.

hazardous situations resulting from the unintended behaviour of the system under development. This was carried out by a team of experts on road and vehicle safety in order to minimise the probability that any essential situation was overlooked. Moreover, a risk assessment for the anticipated hazards was also conducted in order to support the definition of design requirements which reflected the levels of *safety* required for the legal and social acceptance of the resulting system. On the other hand, methods such as Failure Modes and Effect Analysis (FMEA) were deployed in order to ensure that the system design would embody values such as *reliability*, *robustness, safety* and *quality*.

Once the system was designed, the brands of the VW group developing the new systems conducted a set of laboratory and driving tests to verify that the system functioned as anticipated and according to the technical, legal, safety and quality requirements defined for ensuring the sustainability of the outcome. Tests were conducted with the participation of experts on different areas (i.e. safety and other vehicle systems working at different brands of the VW group), who provided key knowledge for a comprehensive evaluation of the system. Further, external stakeholders who owned specialized infrastructures were involved for testing the system so that the values of *safety, effectiveness, robustness, reliability* and *autonomy* could be evaluated in a *cost-effective* and *trusted* manner. Then, after all tests confirmed that the MCB functioned according to specifications, the system received approval for series-production and commercialization. Therefore, through the design and development process is possible to find evidences from the Anticipation, Participation, Deliberation, Reflexivity and Responsiveness dimensions.

Finally, the different companies involved in the design and development of the MCB engaged with Euro NCAP during the commercialization stage of the MCB. This engagement was pursued to obtain an external and independent validation of the positive contribution of the new system to the *safety* of vehicles. The publication by Euro NCAP of this validation helped inform potential customers about the characteristics and performance of the new system. Further, this contributed to the differentiation of the vehicles embedding the MCB systems from competitors. So, the participation of Euro NCAP contributed to further embed values such as *trust* and *competitiveness* through the innovation process.

Table 15 Summary of how the dimensions were followed through the innovation process

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Ideation	Selection of new safety system	System design	System development	Commercialization
Anticipation	Anticipation of positive impacts upon the value of *safety* if it would be possible to stop cars as soon as possible to reduce the risks of secondary collisions		Anticipation of the potential impacts resulting from designing, developing and implementing the new system upon values such as *affordability*, *cost-effectiveness* and *competitiveness*.	Anticipation of potential negative consequences resulting from the new functionalities of innovation in order to facilitate a system design which embodies values such as *safety, autonomy, responsibility, quality, reliability* and *robustness.*	Lab and driving tests to assess whether the new system ensures values such as *safety, reliability* and *effectiveness* as expected.	

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Ideation	Selection of new safety system	System design	System development	Commercialization
Participation	Participation in a research project (GIDAS) aimed at enhancing road and vehicle safety. This enabled to get access to valuable data to research how to improve vehicle safety. In GIDAS are involved research centres, medical institutions, injured people in road accidents, experts from the car industry and public administrations concerned with road safety.	Researchers, engineers and developers experts on active and passive safety systems, and representatives from all the relevant areas of the VW group. Responsible of active and passive safety systems from other brands from the VW group.	All relevant areas of VW. Top management	Engineers and developers of passive and active safety systems and other related technologies.	Engineers and developers of passive and active safety systems and other related technologies.	Euro NCAP The aim was to get an external validation of the benefits of the new system aimed at enhancing the *safety* of vehicles.

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Ideation	Selection of new safety system	System design	System development	Commercialization
Deliberation		Discussions on the feasibility, benefits and shortcomings of different technical solutions to stop the vehicle in case of lateral collisions.		Discussions on the potential hazardous situations and risks related to the functionalities of the new system.		
Reflexivity	Would it be possible to improved *safety* in case of lateral collisions?	Could existing technologies help stop vehicles in a reliable and safe manner? Which technical solution could be implemented in a cost-effective and effective way?		In which hazardous situations could drivers be involved? What are the risks related to the new system? What failures could be a threat to the *safety* of drivers and other road users? What functionalities should the new system entail in order to ensure that drivers keep the *responsibility* to act to avoid a risky situation?	What issues could affect negatively the *safety, reliability, robustness, quality* of innovation? Does innovation provide the expected levels of *safety, reliability, robustness* and/or *quality*?	

Stages of the innovation process/ Dimensions of RI	Opportunity identification	Ideation	Selection of new safety system	System design	System development	Commercialization
Responsiveness			Decision to design and develop a new system with responds to values such as *safety affordability* and *cost-effectiveness*	Decisions on system design so that prospective outcomes reflect values such as *safety, quality, robustness, reliability, autonomy, responsibility* and *efficiency*.		

Source: Own elaboration from data collected for analysis of the case

6.3.2 Analysis of the values

The creation, development and commercialization of the MCB were articulated through an iterative process in which different stakeholders were involved, from opportunity identification to commercialization. The process aimed at generating innovation outcomes which enhanced the value of *safety* of vehicles and road systems through reducing the odds of secondary collisions to occur. To achieve so, the VW group and its network ensured care of a set of values necessary for the acceptability, desirability and sustainability of outcomes. At the early stage of the process, technical solutions to prevent cars from invading the opposite lane were assessed by experts against the values of *affordability, effectiveness* and *cost-effectiveness*. This was done to ensure the acceptability of prospective innovation by two key stakeholders, customers and Top management. Later, the design and development of the new safety concept encompassed a process which forced engineers and developers to conduct hazard and risk assessments as well as several lab and driving tests to ensure that outcomes would embody certain values for sustainability, such as *reliability, robustness*, *effectiveness, quality, legality, responsibility* and *safety.* Thanks to that way of proceeding, engineers were able to anticipate that the *safe* use of the new system would require that drivers had to be able to decide at any time on the most appropriate manoeuvre to overcome or reduce the consequences of a risky situation. This led to a system design in which drivers could always exert control upon the vehicle, even if the MCB was functioning, through the deactivation of the MCB by pressing the brake and/or accelerator[54]. This enabled the embedment in innovation of another value essential for acceptability: *autonomy*.

Summarizing, the activities performed by the different stakeholders through the innovation process enabled to embed in innovation certain values for ensuring the sustainability of innovation outcomes. In particular, the list of values considered for ensuring the ethical acceptability, social desirability and sustainability of outcomes (von Schomberg 2013) consisted of: *safety, reliability, effectiveness, responsibility, robustness, quality, autonomy, affordability, cost-effectiveness, competitiveness* and *trust.*

[54] The MCB is not deactivated if drivers press the brake and/or accelerator <0.5 s after an accident to avoid the deactivation of the system by involuntary acts.

Table 16. Values considered with regard to stakeholders affected and/or concerned with innovation

Stakeholder	Value Proposition
Driver	Safety, affordability, trust, reliability, robustness, quality, effectiveness and autonomy
Other road users	Safety
Car maker	Competitiveness, responsibility, trust and cost-effectiveness
Regulators	Safety, responsibility, trust, reliability, robustness, quality, effectiveness
Consumer protection associations	Safety, responsibility, trust and cost-effectiveness

Source: Own elaboration from data collected for analysis of the case

6.3.3 Analysis of the goals of sustainability

Cars are the most important personal transportation means in developed countries. Their use allows people to travel to their work places faster and comfortably. Further, cars enable people to travel to destinations where to enjoy the nature and/or their free time. But cars, as part of a complex road transportation system, are also an important source of social and political concern due to the high number of casualties and injured people associated with road accidents. Therefore, responsible innovation entails addressing the problem of road safety in order to reduce the social consequences of using vehicles as a transportation means.

The MCB contributed to a more socially sustainable mobility by enhancing the *safety* performance of vehicles in case of an accident. The new functionality enabled a better control of the vehicle and reduced the likelihood of secondary collisions to occur. Thus, the potential number of victims and the consequences of an accident could be significantly reduced.

On the other hand, the deployment of MCB contributed to the goal of economic sustainability in different ways. On the one hand, it had the potential to reduce the economic losses related to road accidents as it may reduce the number of vehicles involved in an accident and its consequences upon human health and vehicles. On the other hand, the MCB was designed for a reliable, efficient and effective functioning throughout its lifecycle and implemented in all new vehicles with minimum increase of price. Thus, the car makers and their network contributed to economic sustainability by making compatible the values of *affordability, cost-effectiveness* and s*afety.*

Finally, the commercialization of the MCB did not contribute to the goal of environmental sustainability, but it did neither imply new negative environmental impacts. This is due to the fact that MCB did not involve adding any new hardware. The implementation of the MCB involved only the development and implementation of new functionalities through software. Therefore, the enhancement of *safety* did neither enhance nor compromise the environmental performance of vehicles.

All in all, the values considered through the innovation process contributed to the generation and implementation of an innovation which supports to transition towards a more social and economic sustainable road system, without further compromising the natural ecosystems.

Table 17. Contribution of the considered values to the goals of social, economic and environmental sustainability

Values	Dimensions of sustainability		
	Environmental	Economic	Social
Safety	X	X	X
Affordability, cost-effectiveness, competitiveness		X	
Reliability, robustness, quality, effectiveness		X	X
Responsibility and trust		X	X
Autonomy			X

Source: Own elaboration from data collected for analysis of the case

6.4 Conclusions

How dimensions for RI were followed

This chapter has showed an innovation process aimed at creating and commercializing a new vehicle safety system. The analysis of the case has depicted that those involved in innovation deployed a set of activities and methods which enabled the innovation process to follow the five dimensions of RI. This contributed to the consideration and embedment of certain values in innovation.

Evidences of the Anticipation dimension were observed through the innovation process. At the early stage of the process, the anticipation of the positive impacts upon vehicle safety of a technical solution for preventing vehicles from invading the opposite lane prompted firm's efforts to generate such solutions. In later stages, the anticipation of the potential negative impacts of prospective innovation upon drivers and other road users prompted efforts to ensure values such as *safety, quality* and *reliability.* Finally, firms performed lab and driving tests in order to assess whether the prospective

systems would work, once commercialized, as expected. This permitted to reduce risks and ensure that innovation outcomes would perform according high standards of *quality, safety, effectiveness* and *reliability*.

On the other hand, it was found that the participation of the car maker in a particular project enabled to get access to data which resulted crucial for the identification of a new opportunity for innovation. Further, the participation of several experts through the process facilitated the identification of risks and, therefore, potential negative consequences resulting from innovation. This contributed to manage risks in order to ensure the sustainability of outcomes. Moreover, it was found that the participation in the process of other stakeholders, such as Euro NCAP, helped visualize the positive impacts of innovation upon *safety*. This contributed to the embedding of other values for sustainability in innovation, such as *trust* and *competitiveness.* In this case, potential users were not engaged directly. A possible reason that may explain this weak participation of users could be the little degree of ambiguity that companies faced about the desirability of innovation outcome.

This chapter depicted that deliberations were also deployed through the innovation process. Deliberations were used as a mechanism to explore workable technical solutions and agree on the trajectory of innovation so that this could be acceptable for all involved stakeholders. Here, deliberations involved experts on vehicle safety as well as marketers and other representatives from the most relevant areas of the company, who assessed prospective innovation outcomes from the value systems of their respective networks: customers, shareholders, regulators, etc.

With regard to the Reflexivity dimension, it was found that prospective innovation was subjected to risk assessment as well as lab and driving tests. These methods were used to generate knowledge about the potential consequences and performance of the prospective innovation. This knowledge was used to foster reflections on whether innovation would ensure certain values, such as *autonomy, safety, reliability* and *quality.* This way of proceeding enabled to assess the implications of innovation and to make informed decisions to ensure that the MCB reflected key values for enhancing its acceptability, desirability and sustainability.

Through the innovation process, actors involved were responsive to demands from customers and societal actors for safer vehicles. Further, it was found that engineers and developers considered other values and interests such as *affordability, cost-effectiveness*, *reliability* and *quality,* relevant for drivers, shareholders, regulators and other road users. The fact that innovation was incremental in nature entailed in this case a low degree of ambiguity about the values that needed to be considered for sustainability. This may explain why firms did not engage with users or other stakeholders in order to

frame issues with regard to innovation or to assess whether innovation outcomes responded to stakeholders' values and interests.

Values

The methods and activities performed through the innovation process enabled firms to care and ensure care of a lists of values which enhanced the ethical acceptability, social desirability and sustainability of the MCB. In particular, the case reflected how those in charge of the design and development of innovation focused their efforts on embedding in innovation values such as *affordability, reliability, robustness, safety, quality* and *cost-effectiveness.* This are essential values for the responsible commercialization of any product, but even more important for safety systems. As a result of the consideration of values listed above, it was possible to commercialize a new safety system which shared its benefits among all involved stakeholders without imposing new burden upon society.

Ensuring the goals of social, environmental and economic sustainability

It was found that innovation outcomes contributed positively to more economic and socially sustainable road mobility, without imposing new burdens upon the environmental dimension of sustainability. Therefore, it can be concluded that the MCB can be considered as an instance of responsible innovation.

7 Cross-Case Analysis and Testing Propositions

7.1 Introduction

Three cases from the car industry have been studied in this research. In each case, an innovation process and its related outcomes have been analysed. The first case refers to an innovation process aimed at commercialization of electric vehicles (EVs) in Spain. The innovation process resulted in a new mobility service concept based on electric vehicles for the tourism industry. The second is an innovation process which resulted in the embedding of two Advanced Driver Assistance Systems (ADASs) in SEAT vehicles. The third case is an innovation process that resulted in a new system, called Multi-Collision Brake (MCB), which decreases the consequences of accidents by reducing the likelihood of secondary collisions to occur.

In this chapter, the results from the analysis of the three cases are discussed (Section 7.2) before the propositions elaborated in this research are evaluated (Section 7.3).

7.2 Cross-Case Analysis

The analysis of the cases selected for this research shows evidence of the five dimensions through the three innovation process. These dimensions, it was found, played a role in the identification, consideration and/or embedding of certain values for sustainability in innovation outcomes. Hereafter, I will discuss some common patterns and differences that can be observed in comparing the three cases studied.

All three cases show that the use of foresight methods, the anticipation of positive and negative impacts associated with innovation, as well as the assessment of the performance of innovation in an anticipatory manner, were fundamental to the consideration and embedment of certain values for economic, social and environmental sustainability. The contribution of the anticipatory activities and methods deployed can be considered highly multifaceted as presented in the following:

- The ADASs case and the MCB case show that the anticipation of positive impacts of certain technical solutions upon *safety* of drivers and other road users prompted efforts to embed those values in innovation outcomes.
- The ADASs and the MCB cases illustrate that the assessment of the alternative concepts in an anticipatory manner provided key information for supporting decision making processes. In particular, the assessments from a technical, economic, market, legal and other perspective of concepts and technologies enabled foreseeing how prospective innovation would impact

certain values essential for sustainability, such as *cost-effectiveness* and *competitiveness.* This information led to the selection of certain options, which ensured care of the above values, and to discard alternative ones.

- All three cases show that the anticipation of hazardous situations and risks associated with the prospective innovations contributed to the embedding of the value of *responsibility* through the innovation process. In the EVs case, the anticipation of risks was performed through deliberations among engineers, business experts, marketers and other stakeholders. As a result, new requirements were set with regard to certain technologies to reduce as much as possible potential negative impacts (e.g. driver distractions and accidents) upon certain values, such as *safety*. In the ADASs case and the MCB case, engineers and developers used more structured methods, such as hazard and risk assessments. This provided knowledge which was used to minimise risks and to enhance the embedding in the system design of certain values for the ethical acceptability, social desirability and sustainability of outcomes, such as *quality, reliability, safety, autonomy* and *robustness.* Further, in ADASs and MCB cases, an array of lab and driving tests were conducted to assess in an anticipatory manner that outcomes would ensure care of the above values.
- In the EVs and ADASs cases, certain requirements were defined to avoid or minimise future negative impacts upon human health and/or environmental systems (e.g. ensuring the use of renewable energies, prohibiting the use of toxic materials and stimulating the used of materials that could be recycled). This can be considered as an anticipatory strategy, stimulated mainly by regulations in the ADASs case, and more by a reflexive exercise about the potential consequences of using different energy sources in the EVs case.
- The EVs and ADASs cases show that foresight methods were deployed to support the analysis of a complex and uncertain environment. This provided useful insights about which issues, needs and values needed to be considered for enhancing the acceptability, desirability and sustainability of innovation outcomes.

The analysis of the cases shows that in the EVs case there was a more intense participation of stakeholders through the innovation process than in the other two cases. In the EVs case, apart from the car maker, potential users of different service concepts were engaged in order to assess whether outcomes would cater to their values and needs. They were also involved for exploring how to make the new service concepts more attractive from the user perspective. Further, SEAT engaged with different organizations (tour operators, public administrations, companies providing services to cruise lines and software companies) in order to tap into necessary resources (ideas, technologies, networking, knowledge, etc.) to create an attractive and sustainable value proposition. The participation through the

innovation process of both stakeholders influenced the trajectory of innovation, contributing to make it more desirable and sustainable. In the MCB case the participation of car makers and other stakeholders concerned with road safety in the GIDAS project allowed generating valuable resources (data) to explore how to enhance the embedding of the value of *safety* in vehicles. Further, several experts on different technologies and areas participated actively through the innovation process in order to ensure that the new system would embody other values, such as *quality, reliability, effectiveness, cost-effectiveness, affordability* and *robustness*. Similarly, representatives of the different areas of the company were engaged in the ADASs case to ensure that the selected ADASs would cater to the values and interests of all concerned stakeholders, including users, other road users, regulators and shareholders. In these two cases (ADASs and MCB) (potential) users were not involved in the design process. Instead, in the ADASs case potential customers were involved through the new car development process in order to know what potential customer would expect and confirm that selected systems would cater to their values, needs and expectations.

Deliberations among stakeholders were used through all three innovation process to deal with complex innovation related issues and to support decision making processes. It was found that discussions and debates were used by innovators to explore issues and assess alternative action paths according to the values and perspectives of the involved stakeholders and their network. Thus, in the EV case deliberations were used as a means to generate a list of issues which could affect positively and negatively the adoption of EVs. This helped generate ideas which would fit with user values and needs as well as with prospective technological, social and economic developments. Further, innovators engaged with potential users and other stakeholders affected with innovation through deliberations in order to assess whether prospective innovations would fulfil their values, needs and interests, as well as to gather key information to enhance the desirability and sustainability of the prospective services. On the other hand, in the MCB case it was found that deliberations were used by experts on safety systems and other stakeholders to explore the pros and cons of alternative technical solutions to stop crashed vehicles in a *cost-effective* and *reliable* manner. Finally, in the ADAS cases, deliberations were used to assess the pros and cons of adopting certain ADASs as well as to engage with potential users.

In the three innovation processes studied, it was found that participants reflected on how certain issues could affect the sustainability of innovation outcomes. For instance, in the EVs case it was found that the analysis of customer experience prompted reflexive behaviours which enabled the identification of undesirable situations (e.g. robberies, car accidents or car breakdowns) that could affect negatively the desirability, and therefore the sustainability, of innovation. This generated plans for ensuring care of values such as *care* and *safety*. Similarly, in the ADASs case the evaluation of user values and needs as well as other environmental cues allowed innovators to reflect on which technological solutions would

be the most appropriate for adoption. On the other hand, it was found that reflexivity about potential negative effects of innovation was stimulated in a structured manner in the ADASs and MCB cases through the deployment of certain methods to identify and assess risks associated with innovation. This provided key insights to enhance the embedding in innovation of certain values, such as *safety, autonomy, robustness* and *quality.* Besides, in these two cases the realization of multiple lab and driving tests ensured reflexivity through the process by stimulating engineers and developers to evaluate the performance of prospective innovations, to identify potential issues affecting their *effectiveness, safety, reliability* and/or *robustness*, and to plans for modifications in order to warrant that systems would ensure care of those values.

The analysis of the three cases also shows that those in charge of the different innovation processes were responsive to the values, interests and needs of diverse stakeholders. In the EVs case, innovators engaged with potential users, potential partners and other stakeholders affected with innovation outcomes in order to understand which values, needs and interests would have to be considered in order to enhance the acceptability, desirability and sustainability of different mobility services. The analysis of this case illustrates how those contacts prompted decisions aimed at embedding certain values in innovation, when it was technically and economically feasible. Further, it was found that, as new knowledge about potential negative consequences resulting from innovation emerged, SEAT and its stakeholders adopted corrective measures to ensure care of essential values for sustainability, such as *safety*. On the other hand, in the ADASs and MCB cases, innovators were responsive to customer and societal demands for a safer mobility. They were also responsive to other user and societal values, such as *reliability, recyclability, quality, effectiveness* and *robustness,* indispensable for ensuring a high protection of human health and an adequate protection of environmental systems. These values embedded in the innovation process by a set of requirements used in the design and development of outcomes.

The activities and methods deployed through the innovation processes studied enabled the embedding in innovation outcomes of a set of values (see Table 16 below for a comparison of values considered in each case). Thanks to the values considered, resulting outcomes contributed to the goals of environmental, social and economic sustainability in different manners (see Table 17 below for a summary of how each innovation contributed to the goals of sustainability). In the EVs case, the values embedded in innovation contributed to a more environmentally friendly mobility. Further, the consideration of certain risks upon the *safety* of drivers and other road users ensured that the social dimension of sustainability was not compromised. With regard to the economic dimension of sustainability, this was maximised as much as possible thanks to the value proposition designed, although other initiatives would be required to ensure the economic sustainability of the production

and commercialization of EVs. Regarding the ADASs and MCB cases, the values considered through the innovation process enabled the generation of outcomes which contributed positively to social and economic sustainability. Both innovations contributed to a more socially sustainable mobility. With regard to the environmental dimension of sustainability in the ADASs case, actions were taken to ensure an acceptable level of environmental protection. In any case, the analysis performed shows that reflexive behaviours focused on economic and social aspects, and less on environmental issues. Therefore, it is possible to speculate that a more reflexive approach to the potential environmental impacts of the materials used for the manufacturing of the involved systems could contribute further to environmental sustainability.

Table 18. List of values embedded through the innovation processes studied

VALUES EMBEDDED IN INNOVATION		
Case I- EVs	Case II- ADASs	Case III-MCB
Accountability	affordability	affordability
Affordability	competitiveness	autonomy
always-connected	cost-effectiveness	competitiveness
Autonomy	effectiveness	cost-effectiveness
Care	efficiency	effectiveness
Comfort	environmental friendliness	quality
Competitiveness	legality	reliability
Cooperation	quality	responsibility
Efficiency	recyclability	robustness
environmental friendliness	reliability	safety
Fun	responsibility	trust
Profitability	robustness	
Quality	safety	
Safety	trust	
Trust		

Source: Own elaboration from data collected for analysis of the case

Table 19. Contribution of each innovation outcome to the goals of economic, social and environmental sustainability

	Sustainability Dimensions		
Cases	Environmental	Social	Economic
EVs	●	◐	◐
ADASs	◐	●	●
MCB	◐	●	●

● Positive
◐ Low contribution
○ Negative

Source: Own elaboration from data collected for analysis of the case

7.3 Evaluating the Propositions

In Chapter 3 seven propositions have been elaborated suggesting how the different dimensions for responsible innovation can support firms in their effort to innovate more responsibly. Hereafter, these propositions are evaluated based on the results of the cross-case analysis presented in the previous section.

Propositions regarding the Anticipation dimension

P1A: The analysis in an anticipated manner of the potential consequences of innovation results in making decision to exploit the positive impacts upon values for sustainability, and/or to mitigate or avoid the negative ones.

P1B: The generation of knowledge about the context in which innovation will be deployed results in efforts to embed in innovation those values which may determine the acceptability, desirability and sustainability of innovation outcomes.

Proposition P1A assumes that the anticipation of consequences resulting from innovation supports responsible innovation. This proposition has been confirmed by case study results. Evidence was found in the ADASs and MCB cases that the anticipation of positive impacts of certain technologies or technical solutions upon societal values, such as *safety,* prompted efforts to take advantage of those potential benefits. On the other hand, all three cases show that innovators deployed activities and methods, such as workshops, lab and driving tests, and risk assessments, to anticipate potential negative impacts associated with the prospective innovation. The identification of potential negative impacts prompted changes in the design, performance or configuration of involved systems to warrant that innovation would ensure care of certain values for sustainability, such as *safety* and *reliability.*

Proposition P1B assumes that the anticipation of the context in which innovation would be deployed contributes to responsible innovation by facilitating the shaping of innovation according to certain issues, needs and values that would be relevant for the sustainability of innovation. The case results have confirmed this proposition. In the EVs and the ADASs cases, innovators anticipated the contexts in which users will move (e.g. urban areas). Then, they used that knowledge for anticipating certain issues and/or customer needs (e.g. *safety* would be enhanced if it was possible to avoid read-end collisions) and for selecting those technological solutions that would be more desirable for that particular context.

Propositions regarding the Participation dimension

Proposition P2 suggests that the participation of stakeholders contributes to responsible innovation.

P2: The participation of stakeholders through the innovation process enables tapping into resources (knowledge, ideas, technologies, networking, etc.) necessary for enhancing economic, social and/or environmental sustainability.

The case results have confirmed P2. The EVs and MCB show that innovators engaged with other stakeholders in order to tap into resources which enabled the embedding of certain values in innovation outcomes. On the other hand, the EVs and the ADASs cases show that the participation of stakeholder, such as potential users, through the innovation process helped generate knowledge about their values and expectations. This knowledge was then used by innovators to shape the features of prospective innovation so that this would cater to the identified values and needs of stakeholder.

The case results would also suggest that the degree of involvement of different stakeholders through the innovation process could vary according to different factors. Thus, the case results would suggest that innovators attempting to innovate responsibly would engage more actively with users and other affected and/or concerned stakeholders when there are high levels of uncertainty regarding the acceptability and/or desirability of innovation. Further, they would engage through collaborative actions with different stakeholders when complementary resources were needed to embed certain values for sustainability in innovation. On the other hand, innovators pursuing responsible innovation may need to engage with fewer different types of stakeholders when they are dealing with innovations over which there is less uncertainty about its acceptability, desirability and/or sustainability. All this may have important practical implications for those attempting to innovate responsibly as it may affect how the innovation process is organized for ensuring that responsibility issues are properly considered.

Deliberation dimension

Proposition P3 suggests that responsible innovation would benefits if stakeholders are engaged through deliberations.

P3: Deliberations among stakeholders through the innovation process results in decision making which increase the acceptability, desirability and sustainability of innovation outcomes.

With regard to proposition P3A, the case results provide evidence that confirms it. Deliberations were used in all three cases by those in charge of the innovation process to deal with varied innovation related issues. Examples abound in all three cases. Deliberations were used to support decision making regarding what values and criteria would be the most convenient for selecting ADAS, what resources would be needed for creating an economically-sound, attractive, safe and environmentally friendly mobility service based on EVs, or for assessing alternative manners to stop vehicles in a cost-effective and safe way (MCB case). In all three cases, deliberations helped innovators to assess issues from different perspectives, and to make decisions regarding innovation so that this would care certain (sometimes conflicting) values that were considered essential for sustainability.

The case results would indicate that the need to involve different types of stakeholders in the innovation process through deliberations may depend on the characteristics of the products of the innovation enterprise. The comparison of the three cases seems to suggest that high degrees of uncertainty and/or ambiguity around the acceptability, desirability and/or sustainability of innovation may require that innovators engage through deliberations with more types of stakeholders than in cases in which innovators are sailing on more familiar grounds. This seems reasonable and in line with the insights observed when P2 was evaluated. To be confirmed, it would have important practical implications for those attempting to innovate responsibly.

Reflexivity dimensions

Proposition P4 suggests that reflexivity is relevant for responsible innovation as it enables identifying issues regarding innovation and planning to enhance its acceptability, desirability and sustainability.

P4: The analysis of the cause-effect relationships between innovation and the context facilitates the identification of impacts resulting from innovation and the adoption of measures to maximise the positive ones and/or mitigate or avoid the negative ones.

The three cases show instances of how innovators deployed reflexive behaviours and processes in order to identify issues related to innovation as well as to decide or plan how to deal with them in order to ensure care of certain values for sustainability, such as *safety, affordability* and/or *reliability*. The EVs

case shows that reflexivity was stimulated in workshops by the deployment of different techniques which enabled, for instance, the identification of potential risks upon *safety* resulting from the use of certain technologies. This prompted decisions to modify the system design to reduce as much as possible the risk of accidents. In the ADASs and MCB cases, the use of risk assessment methods and the deployment of lab and driving tests stimulated reflexivity about the potential negative impacts resulting from innovation. The identification of potentially unacceptable risks or unexpected behaviours of prospective innovation prompted actions to ensure the *reliability, quality, safety* and *robustness* of involved systems. Therefore, the proposition P4 is confirmed.

Responsiveness dimension

The proposition P5 suggests that being responsive to the values, interests and needs of stakeholders may contribute positively to responsible innovation.

P5: The consideration of the values, needs and legitimate interests of stakeholders through the innovation process it enhances social, economic and environmental sustainability, and reduces risks of societal contestation.

The EVs and ADAS cases provide evidence that innovators engaged with stakeholders in order to develop an understanding about the values, needs and expectations that would increase the desirability and sustainability of innovation outcomes. This knowledge was then used by innovators in decision making process to shape innovation accordingly. On the other hand, the MCB case shows that innovators worked in a new safety system as a respond to drivers and societal demands for a safer mobility. Therefore, the case results have confirmed P5.

Propositions relating the dimensions with the outcome of the innovation process

The last proposition, P6, suggests that ensuring care of certain values for sustainability through anticipation, participation, deliberation, reflexivity and responsiveness is a necessary condition for responsible innovation.

P6: Responsible innovation occurs if only if the innovation process follows the anticipation, participation, deliberation, reflexivity and responsiveness dimensions.

The confirmation of this proposition requires validating that in any innovation process resulting in responsible innovation it would be possible to observe evidence of all five dimensions. On the contrary, one single case showing that responsible innovation can be achieved without the consideration of one dimension would suffice for rejecting P6.

Regarding P6, the EVs and the MCB cases show that the activities and methods deployed created innovation outcomes which contributed positively to different dimensions of sustainability without compromising any of them. The analysis of these cases shows that the innovation processes followed the five dimensions. This contributed to ensuring care of certain values. With regard to the ADAS case, the analysis of how goals for sustainability were achieved suggested that innovators focused on the social and economic dimensions, and that the environmental dimension was considered partially. Anyway, this case also shows that the five dimensions were followed through the innovation process. Therefore, the case results have not provided evidence for rejecting P6.

Finally, Table 20 below summarises the evaluation of the propositions and their possible implications.

Table 20. Summary of the evaluation of the propositions and possible implications

	Status	Implication
P1A	Confirmed	The anticipation of the potential consequences of innovation through the innovation process may stimulate the exploitation of positive impacts upon socio-economic and/or ecological systems, and the mitigation or avoidance of the negative ones.
P1B	Confirmed	The anticipation of the context in which innovation would be deployed may prompt efforts to embed in innovation those values which may enhance its future acceptability, desirability and sustainability.
P2	Confirmed	The participation of stakeholders through the innovation process may contribute to obtaining certain resources necessary for enhancing the social, economic and/or environmental sustainability of outcomes.
P3	Confirmed	Stakeholder deliberations through the innovation process may support decision making for enhancing the economic, social and/or environmental sustainability of innovation.
P4	Confirmed	The deployment of reflexive behaviours and/or processes through the innovation process may prompt plans for maximising the positive impacts of innovation upon society, and/or mitigating or avoiding the negative ones.
P5	Confirmed	The deployment of activities and methods which stimulate the consideration of the values, needs and legitimate interests of stakeholders affected and/or concerned with innovation may enhance its acceptability and desirability, and reduce risks of societal contestation.
P6	Confirmed	The anticipation of consequences and contexts, the participation of and deliberation with stakeholders, reflexivity over complex innovation issues and the consideration of values, needs and interests of stakeholders through the innovation process may be a necessary condition for innovating responsibly.

Source: Own elaboration from data collected for analysis of the case

8 Conclusions and recommendations

This chapter presents the conclusions of this research, based on the empirical findings presented in the previous chapter (Section 8.1). It also provides recommendations for further research on the topic of responsible innovation (Section 8.2). Finally, reflection about the topic are presented (Section 8.3).

8.1 Conclusions

In this thesis, my research objective has been to propose and validate a framework for supporting firm to innovate more responsibly. In order to achieve this research objective, we conducted an extensive literature research in search for theories and models of innovation which could provide a suitable framework to embed responsibility issues through the innovation process. As a result, it was found that the existing models and theories of innovation, including the Linear and Interactive models, the Innovation Systems Models (NIS, SIS and TIS), the Open Innovation Model and the Sustainable Innovation approach, provided little guidance on how to deal with issues of responsibility through the innovation process. On the other hand, the review of the emerging approach of Responsible Innovation provided promising mechanisms to address the research objective of this thesis. So, a theoretical framework was developed based on the emerging theories for innovating responsibly. This suggested certain mechanisms which could be used by firms to innovate more responsibly. In particular, the framework suggested that firms may embed issues of responsibility through the innovation process by ensuring care of certain values for achieving the goals of social, economic and environmental sustainability. Further, the theoretical framework stated that ensuring care of those values would require that the innovation process followed five dimensions, i.e. Anticipation, Participation, Deliberation, Reflexivity and Responsiveness. Therefore, the literature research allowed developing a theoretical framework consisting of certain mechanisms to support firm to innovate responsible. On the other hand, the literature review revealed that the proposed mechanisms for embedding responsibility issues in innovation, although promising, would require further testing before they can be considered as useful for practical application in different contexts and business settings.

To test the theoretical framework I have evaluated three cases selected from the car industry. Each case consisted of an innovation process that resulted in outcomes contributing to the goals of social, economic and/or environmental sustainability. The first case was the commercialization of electric vehicles (EVs) case. This focused on an innovation process aimed to generate new business opportunities around EVs for the Spanish market. This innovation process resulted in a new mobility service concepts aimed at the tourism industry, which enabled tourists to sightsee in a clean, affordable

and fun manner. The second case was the new Advanced Driver Assistance Systems (ADASs) case. This was an innovation process aimed to select and adopt safety- and comfort-enhancing systems according to user values and expectations, firm strategy and competitive landscape. This innovation process resulted in the adoption by a car maker of three new ADAS systems which enhanced the safety of both vehicle occupants as well as other road users. The third case was the Multi-Collision Brake (MCB) system case. This case was an innovation process aimed to design, develop and commercialize a new safety system, the Multi-Collision Brake (MCB). The MCB increases the safety of vehicles, and therefore the road safety, by reducing the likelihood of secondary collisions to occur. This contributed to reduce the number of car and people involved in an accident as well as its consequences upon human integrity and well-being.

Empirical conclusions

The testing of the theoretical framework for responsible innovation has provided a set of conclusions regarding how innovation processes can be deployed for increasing the likelihood of generating innovation outcomes which are economic, environmental and socially sustainable. The conclusions resulting from the empirical research part of this thesis, and their practical implications, are the following:

- A first conclusion is that involving into foresight for innovation and its different aspects through the innovation process seems a helpful mechanism for responsible innovation. The anticipation of the positive consequences upon society of prospective innovation may help set goals and direct efforts in directions that are more socially desirable. On the other hand, the deployment of anticipatory activities for generating knowledge about the potential negative consequences of innovation upon socio-economic and ecological systems enables innovators to address potential issues before they materialize. This helps take care for certain values necessary for enhancing the ethical acceptability, social desirability and/or sustainability of innovation. Further, the anticipation of the context in which innovation will be deployed may contribute to responsible innovation by stimulating the early consideration in the design and development of innovation of the issues, needs and values that may determine the acceptability, desirability and sustainability of outcomes.
- Responsible innovation seems contingent upon the participation of stakeholders through the innovation process. The participation of stakeholders enables innovators to access resources (knowledge, ideas, networking, technologies, etc.) required for considering and embedding in innovation certain values for social, economic and environmental sustainability. Interestingly, gained insights through the empirical research would suggest that the acceptability, desirability

and sustainability of innovation outcomes may require the participation of stakeholders beyond potential users. Therefore, innovators may need to involve with those affected and/or concerned with innovation outcomes in order to act responsibly. The practical implication of all this for those attempting to innovate responsibly is that all stakeholders need to be identified as soon as possible. Then, innovators may assess how stakeholders can contribute to enhance the social, economic and environmental sustainability of prospective outcomes, and plan carefully how to stimulate effective participation of all involved stakeholders through the innovation process.

- Responsible innovation implies problem-solving in which there are often multiple and contradictory values at play. Therefore, responsible innovation calls for mechanisms to deal effectively with the multiple demands revolving around innovation in order to enhance its social, economic and environmental sustainability. Deliberations seem to be one of these mechanisms according to the results of this research. Deliberations contribute to responsible innovation by facilitating decision making processes in which it is necessary to come to trade-off solutions which cater to the values, needs and expectations of involved stakeholders. The practical implication for those attempting to innovate responsibly is that they should promote the creation of forums in which the voices and interests of stakeholders can be represented effectively. These forums should aim at gathering opinions, demands and ideas of stakeholders for enhancing the acceptability, desirability and sustainability of innovation outcomes.
- Another conclusion of this research is that reflexivity may be a useful mechanism for helping firms to innovate responsibly. The deployment of reflexive behaviours and processes through the innovation process support responsible innovation by stimulating innovators to explore and assess how innovation would relate to the context. This allows making plans to change, if necessary, the goals and features of innovation to enhance the embedding of certain values for sustainability. The practical implication of this conclusion is that those involved in innovation ought to ensure that the innovation process encompassed activities in which different stakeholders are stimulated to reflect on and generate new insights about how the prospective innovation may support or weaken the goals of sustainability. As the potential implications of innovation may not be evident from the outset, reflexivity may be stimulated at different stages of the innovation process. Further, effective reflexivity may require the involvement of different stakeholders, who bring into the process key resources to explore the wide implications of innovation upon socio-economic and ecological systems.
- The fifth conclusion of this thesis is that responsiveness is a helpful mechanism for enhancing the sustainability of outcomes as well as reducing the risks of societal contestation. Thus, responsiveness stimulates innovators to generate insights about the values, needs, concerns

and interests of different stakeholders affected and/or concerned with innovation. Responsiveness also involves the application of this knowledge through the innovation process to enhance the sustainability of outcomes. The practical implication of this conclusion is that innovators need to implement methods which allow them to engage with stakeholders in order to gain insights about those values and concerns that may affect the sustainability of outcomes. Then, this insights need to be assessed and used as design, development and/or commercialization requirements to enhance sustainability of outcomes. Further, innovators attempting to innovate responsibly need to establish processes which facilitate that emerging information about the potential consequences of prospective innovation is the object of deliberation and reflexivity. This may enable innovations to react in front of unexpected and undesirable impacts before innovation is commercialized.

- The last conclusion is that the theoretical framework of RI adopted in this dissertation seems a helpful *tool* for explaining how responsible innovation occurs. This means that firms attempting to innovate responsibly may organize their innovation processes so that they ensure care for certain values for sustainability. To achieve so, this research has provided evidence that the five dimensions of RI can be helpful mechanisms.

Finally, and coming back to the research objective of this thesis, to indicate that we have achieved to propose and validate a framework that it will help, plausibly, firms to innovate more responsibly.

8.2 Recommendations for further research

Responsible Innovation is an emerging and developing approach of innovation. As such, it can be said that RI is still in its infancy and therefore there is much to research on how to promote and implement a more responsible approach to innovation, especially in the business field. As outlined in Section 2.4.2.2, most research to date about RI has focused on how to reduce the risks associated with certain technologies and on the early stages of the innovation process (research projects and early stages of the development of technologies, mainly). This Thesis has provided a validated framework for promoting RI through the whole innovation process at the firm-level, but there still is much to research before we know how to foster RI efficiently in different contexts and industries. So, one possible line of future inquiry would be to explore how to implement in an effective way the framework validated in this thesis in different contexts. In literature, it is possible to find first attempts to implement alternative frameworks of RI in research contexts (Stilgoe, Owen et al. 2013) but there is not equivalent examples in business contexts so far. Therefore, it would be relevant from a scientific and practical point of view to explore how the framework for RI adopted and validated in this dissertation can be embedded in innovation practice at the firm-level.

If RI gets traction and is deployed in different companies and sectors, it may be interesting to investigate under which conditions RI is successfully adopted. It may prove that the adoption of RI by firms may depend on many contextual factors (e.g. firm size, competitive landscape, market and public pressures, regulation frameworks, cultural settings, etc.) So, it would be interesting to track and analyse the attempts made for implementing RI in different contexts. This may allow identifying which factors may promote and hinder the adoption of RI at the firm-level. The knowledge about the drivers and barriers for adoption this new approach may facilitate the formulation of strategies and policy instruments to overcome barriers for more responsible innovation.

A particularly interesting research area it can be to explore the development of toolkits for RI, and especially aimed at small and medium-sized enterprises (SMEs). These companies are key for the competitiveness and development of modern societies and they play a key role in the development and commercialization of certain technologies, such as nanotechnologies (Association 2015). On the other hand, they face specific challenges when it comes to innovation because their resources are much more limited than those of a large company. Literature indicates that, in many cases, technology developers often lack the capacity and skills required to assess risks of new technologies (Köhler and Som 2014). This may be a particular barrier for the adoption of RI in the context of SMEs which deserves the development of specific instruments.

Finally, most research related to RI has focussed on how to avoid irresponsible behaviours with regards to innovation and less to investigate how to foster the development of innovation aimed at tackling the serious and important challenges of sustainability to which modern societies are faced. Therefore, it would be interesting to research on this particular and distinctive feature of RI (Owen, Macnaghten et al. 2012). RI invites us to dream, to think collectively about what future we want and what innovations we need to achieve it. The implementation of this way of innovating will surely require special platforms and new methodologies to bring together different actors and resources. Here, it is possible to sense that RI can complement and learn from other existing approaches related to sustainability, such as Transition Management (Loorbach 2002; Kemp and Loorbach 2003; Kemp, Loorbach et al. 2007; Loorbach and Rotmans 2010), Strategic Niche Management (Kemp, Schot et al. 1998; Kemp, Rip et al. 2001; Schot and Geels 2008) and Backcasting (Vergragt 2005; Quist 2007; Robinson, Burch et al. 2011).

8.3 Final reflections

What will be the development of RI? Will it become another buzzword? It is difficult to predict what will be the development of this new approach. Currently, RI is gaining much attention. In the coming years, it is possible that we see a more or less large number of publications about this topic. It is also likely that

different companies adopt this concept and apply it in their innovation processes. Reasons to research and development the RI approach will not lack.

The recent development on technologies such as artificial intelligence, drones, communication technologies, biotechnologies, nanomaterials and so on, may create new challenges and have important consequences in our security, privacy, health and welfare. Some go further and see some of these technologies as a serious threat to our survival as species (Cella-Jones 2014). In any case, it seems evident that as our technological capabilities grow, so do the risks that we face. In the past, there were civilizations that succumbed to their own unsustainable practices. Many of them were based on new technological capabilities, new practices, such as agriculture (Diamond 2012). Past civilizations were not able to foresee the consequences of their act, and they paid a high price. Will we be able to act more responsibly? Will we able to devote our efforts to technological and scientific developments that allow us to live in a better world? If something seems clear it is that we know very little about the world around us and that we have acted with unconsciousness, if not frivolity. So far our actions and technologies have had important impacts on socio-economic and/or ecological systems. Many scientists warn us that we need to modify the socio-technological systems that provide us with fundamental services such as transportation, food or energy, if we want to avoid the most negative consequences of climate change. This leads me to believe that there is real and powerful needs to develop RI.

Reflecting on the concept of RI always comes to my mind the other part of the equation: consumers. Are we willing, as consumers, to launch the appropriate signs to stimulate responsible innovation? Will we be able to overcome our own inconsistencies and contradictions? Will we think on the values that are embodied in what we purchase? In short, is it possible responsible innovation without responsible consumption?

These and many other questions have resonated in my head while developing this thesis. Here I will not try to answer them, but to throw them to the reader to stimulate reflection on the need for more responsible attitudes for moving towards more sustainable societies. The truth is that I do not have clear answers either. In any case, I would like to stress the complexity and validity of the concept of responsibility. In an interconnected and complex world, in which our actions may have implications not only for us but for future generations, responsibility should be a central concept. It suggests awareness of the self and of the consequences that our actions can have on ourselves and others. But today we live in a time in which awareness is neither a priority nor stimulated by the environment. We live in a time where time has become a luxury, and time to think, to reflect, and to act on our deepest convictions and values, something almost anecdotal.

Something similar happens in business contexts. The pace is frenetic in most cases. Everything is for yesterday. The pressure to generate income is huge. In this context, issues that are not regulated may be missed, receive little or no attention. Even those things that are regulated, they may be twisted as far as possible on behalf of competitiveness. In this context, the question arises whether there are adequate incentives to act responsibly, or if somehow what is encouraged is the collective irresponsibility.

Finally, I would like to launch a reflection on another aspect that I consider essential for the future development of RI: education on ethical, environmental and social issues. Is the education received by engineers, managers, entrepreneurs, scientists, etcetera, adequate to deal with the complexity and challenges we face? How should academic curricula be modified in order to equip different professionals with the necessary resources to innovate more responsibly? It seems clear that there are significant gaps in education about certain topics important for RI right now. We need to change this if we want our firms to be better prepared for RI.

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Appendix A. Interview Checklist

A1. General information

- Name of the respondent
- Position of the respondent and experience within the industry
- Contribution to the innovation process

A2. The outcomes of the process

- Name of innovation
- Main features and functionalities
- Target customer
- Reasons for its creation and commercialization

A3. The innovation process

- Dates
- Methods deployed in ideation
- Participants in the ideation process
- Methods and criteria for evaluating ideas
- Methods deployed for assessing the consequences of innovative ideas
- Methodology for selecting ideas: who is involved, what is consider, how
- Key environmental requirements considered in innovation development
- Methods for customer involvement through the process
- Motives for customer involvement
- Participation of other stakeholders through the innovation process
- Motives for stakeholder involvement
- Methods for assessing risks associated with innovation before commercialization
- Issues considered through the testing of innovation
- Standards adopted for the development of innovation

A4. Other issues discussed

- Barriers for customers and other stakeholders involvement

Appendix B. List of interviews

Mr. E. Pastor, Dep. de Product Marketing, SEAT, Martorell, interview November 13, 2012

Mr. B. J. Luzón, Dep. de Cálculo Técnico, Centro Técnico de SEAT, Martorell, interviews August 17, 2015 and September 25, 2015

Mr. J. Ventura, Dep. de Product Marketing, SEAT, Martorell, interview December 10, 2012

Mr. M. Estudillo, Dep. de Product Marketing, SEAT, Martorell, interviews October 9, 2012, November 16, 2012 and February 7, 2013

Mr. M. Sánchez, Dep. Product Management, SEAT, Martorell, interviews October 16, 2012 and November 06, 2012

Mrs M. del Mar Villacampa, Dep. Medio ambiente de Producto, Centro Técnico de SEAT, Martorell, May 27, 2014

Mr. O. Mas, Dep. Desarrollo Eléctrico, Centro Técnico de SEAT, Martorell, interview September 10, 2015

Mr. P. Torrellas, Dep. Desarrollo Eléctrico, Centro Técnico de SEAT, Martorell, interview February 7, 2013 and February 8, 2013

Mr. R. Hernández, Dep. Product Management, SEAT, Martorell, interviews November 15, 2012

Mr. U. Eberhard, Dep. Product Marketing, SEAT, Martorell, interview November 20, 2012

Additional contacts

Additional information has been provided by Mr. S. Ilijevic (Centro Técnico de Seat), Mr. J. Caus (Centro Técnico de SEAT), Mr. E. Alcantara (Centro Técnico de SEAT), Mr. D. Compadre (Centro Técnico de SEAT)

ABREVIATIONS

ADAS	Advanced Driver Assistance System
BASt	German Federal Highway Research Institute
CDOs	Collateralized Debt Obligations
CDS	Credit Default Swaps
CRIs	Centres for Responsible Innovation
CTA	Constructive Technology Assessment
Euro NCAP	European New Car Assessment Programme
FAT	German Automotive Research Association
FMEA	Failure Modes and Effect Analysis
GIDAS	German In-Depth Accident Study
ICTs	Information and Communication Technologies
MCB	Multi-Collision Brake
N&N research	Nanosciences and Nanotechnologies research
NGOs	Non-Governmental Organizations
NIS	National System of Innovation
NPOs	Non-Profit Organizations
OITs	Open Innovation Tools
R&D	Research and Development
RAIDS team	VW group in charge of the Road Accident In-Depth Studies
RDI	Research, Development and Innovation
RI	Responsible Innovation
RIS	Regional System of Innovation
RTTA	Real-Time Technology Assessment
SI	Sustainable Innovation
SMEs	Small and Medium-sized Entreprises
SSI	Sectoral Systems of Innovation
TIS	Technological Systems of Innovation
VW	Volkswagen